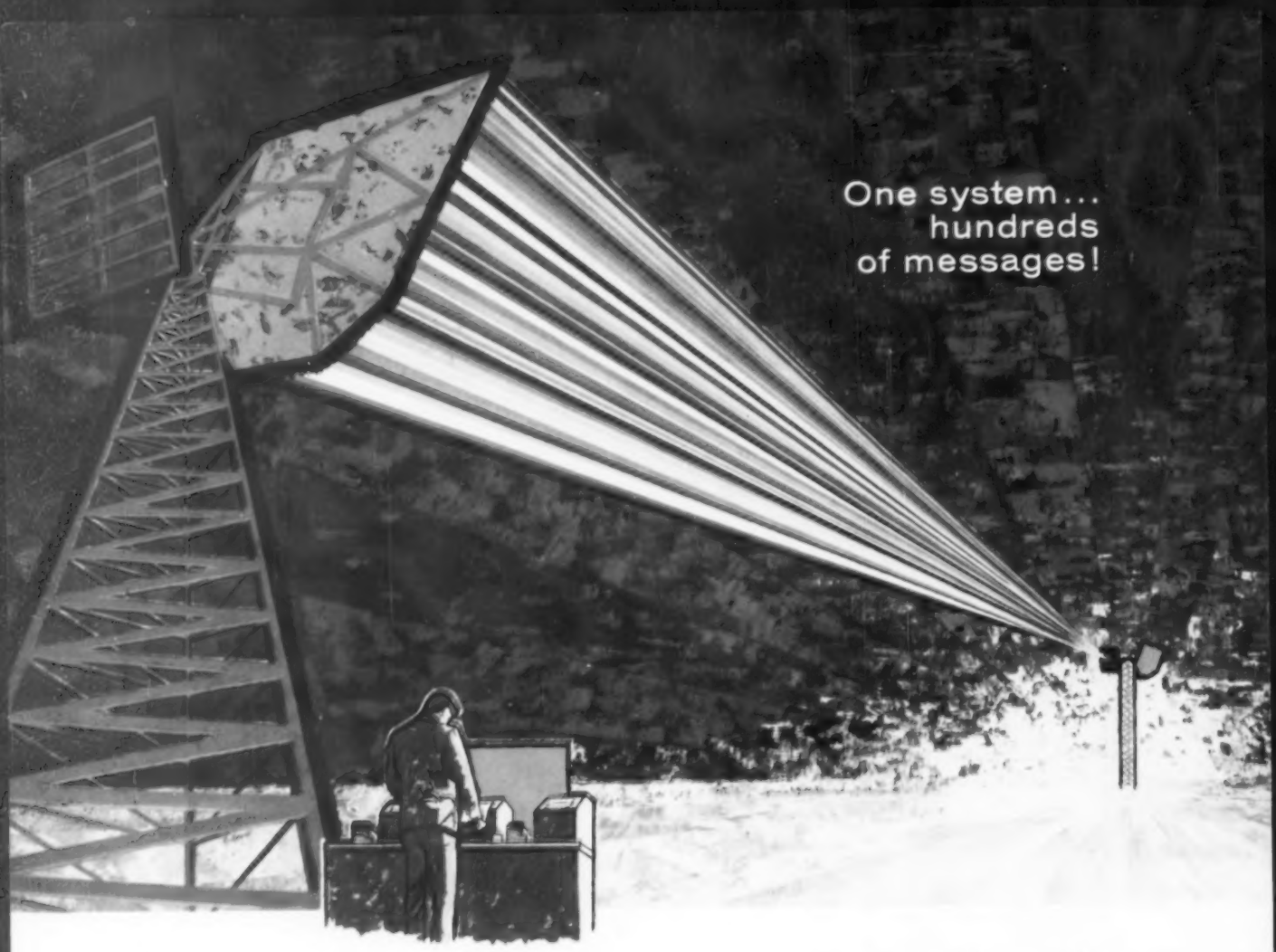
INDUSTRIAL RESEARCH

JUNE-JULY, 1961

one dollar

LIVING IN SPACE

THE MAGAZINE FOR TECHNICAL MANAGEMENT



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THE COVER, *an oil painting of a scientific laboratory in the vicinity of the red planet, Mars (the small globe is the distant sun), is not as futuristic as it might have appeared even a year ago. Man now has stepped into space.*

The major obstacle to a prolonged space expedition is the design and development of life support systems, says Chance-Vought's G. B. Whisenhunt in "Living in Space," starting on page 19.

The cover was painted by New York artist Monroe Eisenberg for Kollsman Instrument Corp. and Industrial Research.

Man's attempt to invade a closer dimension is told in "Flying Cars and the 'Terresphere,'" by Dr. Robert B. Sleight, Applied Psychology Corp.'s president (page 52). Flying cars, near-ground craft that travel in the very-low-altitude sky, are proposed as mass-transportation vehicles.

What is probably the world's longest research project, the English Channel tunnel soon will link the British Isles with Europe. I·R editor & publisher Neil P. Ruzic discusses some unique solutions to the engineering, financial, and political problems in his special report starting on page 41.

Also in this issue, Harrell V. Noble, head of WADD's electronics laboratory, explains the new science of molectronics engineering, and the new type of engineer who makes it work, on page 24. Objective design is proposed by Cornell's John M. Allderige in "Toward a Theory of Design," on page 57. And research director Harold W. Rice calls for "Realistic Research Administration" for the professional execution of industrial research in his article on page 62.

A new department, "Ideas and Applications," is introduced in this issue as pages in a sourcebook (pages 65 and 66) to stimulate the creative process of technical management. ■

46,000 copies of this issue printed.
Circulation audited and verified.

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JUNE-JULY 1961

INDUSTRIAL RESEARCH

THE MAGAZINE FOR TECHNICAL MANAGEMENT

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INDUSTRIAL RESEARCH: *editorial, circulation, and advertising offices, Beverly Shores, Ind. Vol. 3, No. 3, June-July, 1961, published monthly beginning next (October) issue by Scientific Research Publishing Co. Inc.* *(Copyright © 1961).* *Copies of I•R on microfilm are available from University Microfilms, 313 N. First St., Ann Arbor, Mich. (See page 4 for subscription and other information.)*

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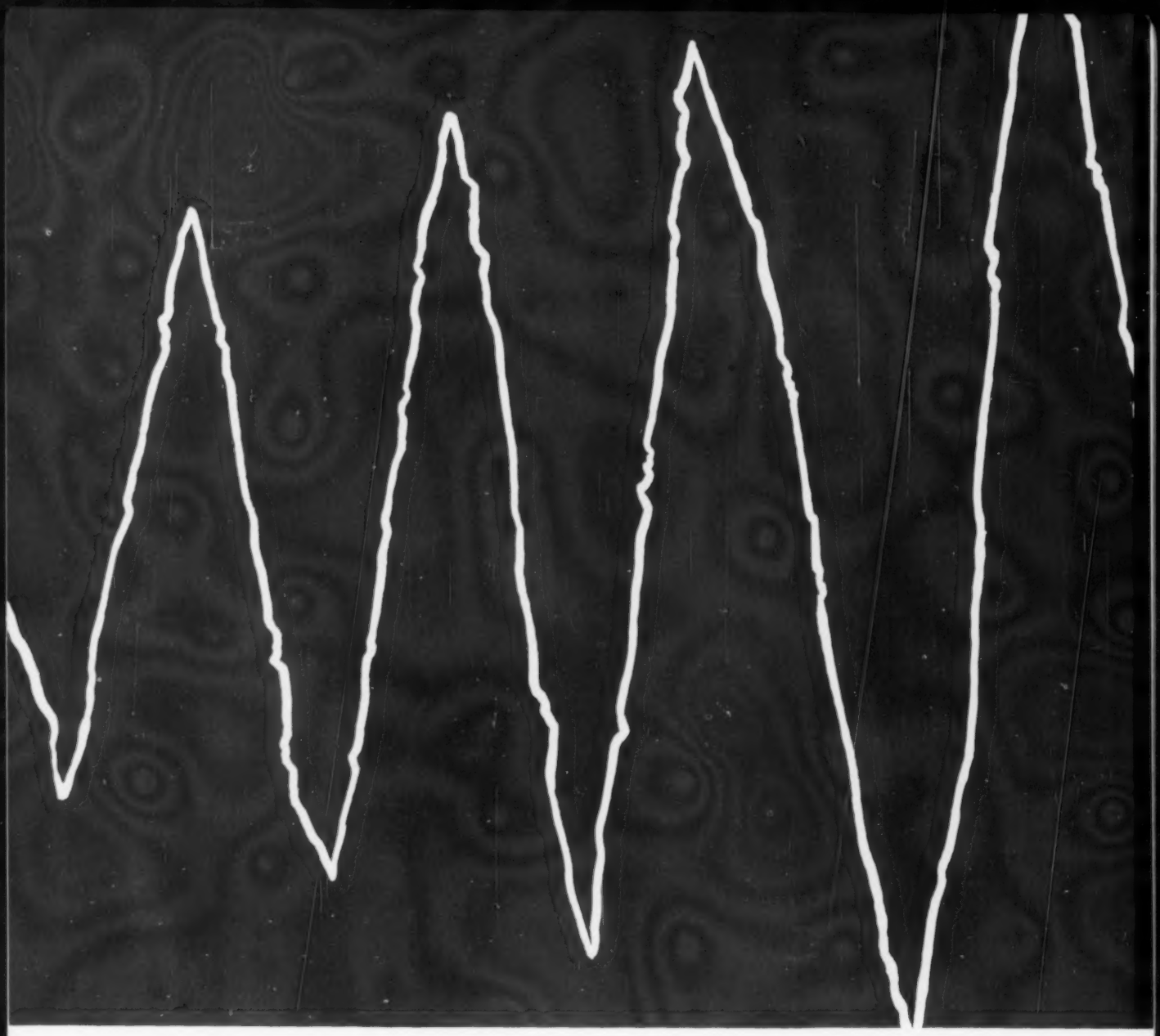

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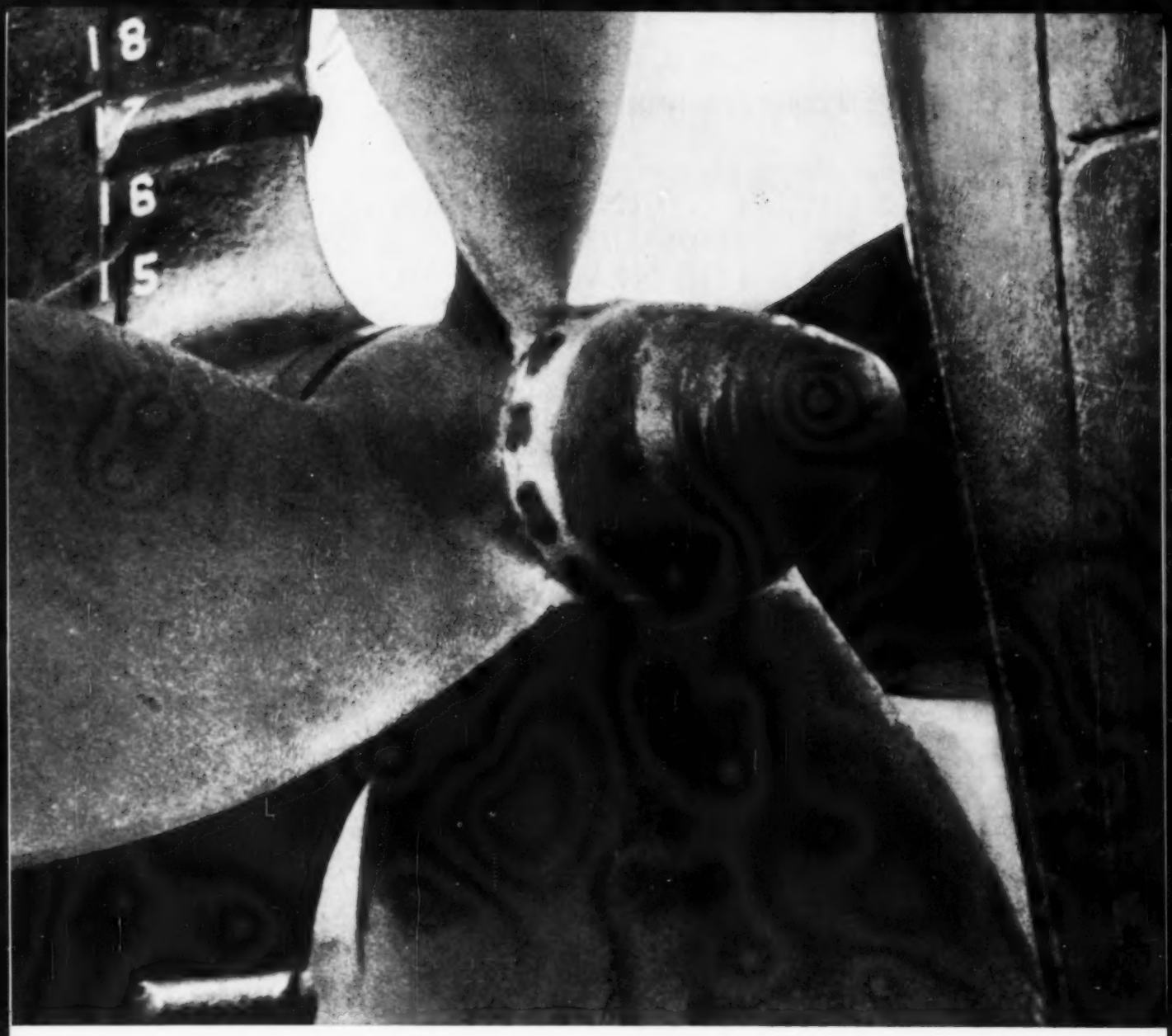

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	Word size 40 bits & sign	_____
	12 decimal digits	_____
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Outputs—Optional	Facitape High Speed Punch	_____
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	Up to four outputs	_____
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	Desk size	_____
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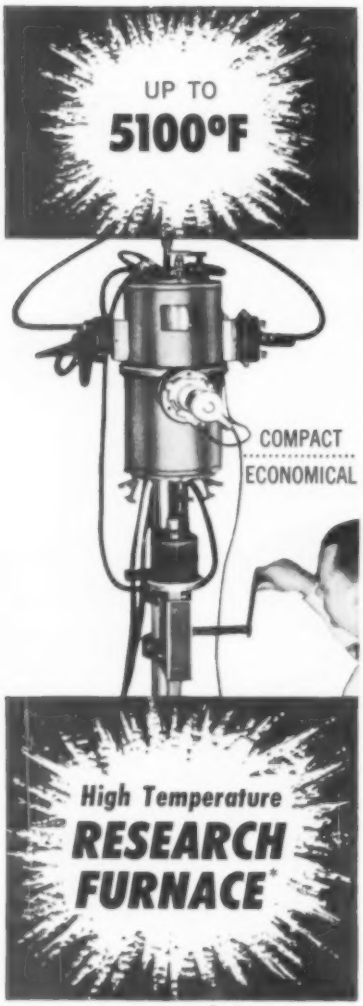

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I•R FEEDBACK *from technical management*

Product development

Sir:

Among the intriguing products discussed by Dr. Charles H. Moore in his article, "The Basic Approach to Product Development" (Vol. 3, No. 2), there are several of particular interest to us because of our function in the National Science Foundation.

The U.S. Antarctic Research Program is coordinated and administered by the National Science Foundation. We feel some responsibility, therefore, for the welfare of our scientific personnel in the Antarctic and for facilitating their researches. For these reasons, the butane-gas camp stove and the hot meal packet illustrated in Dr. Moore's article could be of very practical use to the field parties working in the Antarctic.

G. R. Toney
U.S. Antarctic Research Program
National Science Foundation

Quiet revolution

Sir:

Congratulations on the April-May issue of your magazine, particularly the "Quiet Revolution in Metalworking."

I•R has an important part to play in the immediate future of American manufacturing. I fear unless we somehow make available to the average plant the results of jet age developments in materials, machines, and methods, our economy will be hamstrung.

This field of industrial research, significantly, is completely ignored by the technical publishers and publicists. Yet no other field needs help and assistance as this one does.

Manufacturing engineering, save for a few large concerns, is in a tragically bewildered state, confronted with daily, even hourly, improvements, changes, and substitutions in the materials, methods (or techniques), and machines. Manufacturing processes that were valid and economical yesterday may be and are in many instances completely obsolete today because of these kaleidoscopic changes.

It may not be "research" strictly speaking that is needed, but a systematic, experimental, and therefore scientific, approach must be made to problems of obsolescent methods and techniques. A few of the largest facilities have manufacturing research activities and can hope to keep step with these changes, but the vast majority—the 99%—can only hope that the magazines, the technical communications channels, along with the sales engineers, can assist them to keep from becoming hopelessly outmoded. In fact, 15 years of consulting work in the field of metal removal makes it clear to me that the vast majority of our run-of-the-mill manufacturing plants are operating on an ox-cart level.

A few months ago, by way of example, an application of ceramic facing tool to an automotive (powder metal) part was made with excellent results at the cost of four cents each. Within a month after this solution, burnishing tools came on the market that reduced the cost to one cent. And the cost of tool replacement was less than $1,000. But how could anyone know this without the assistance of a research, better experimental, division, whose sole concern is ferreting out the better techniques and more economical approaches?

We have recently eliminated a subsequent grinding operation on a large shaft for an agricultural machinery manufacturer by applying ceramics which, after a hogging cut, left a finish of 20 micros. But again how could anyone know of this without the help and aid of a division solely concentrating on methods obsolescence?

Horace Frommelt, Director
Manufacturing Research Center
Ferro Powdered Metals Inc.

Symbolic logic

Sir:

The April-May issue of Industrial Research, on the whole, is most impressive. I am very pleased to "be in it." I would be happy to have occasion to contribute to your fine journal again.

While the basic work on my article, "Language Engineering," was done at Douglas, I am now at Ramo-Wooldridge, Canoga Park, Calif., and I would like to have myself identified with my present employer.

H. M. Semarne
Information Systems
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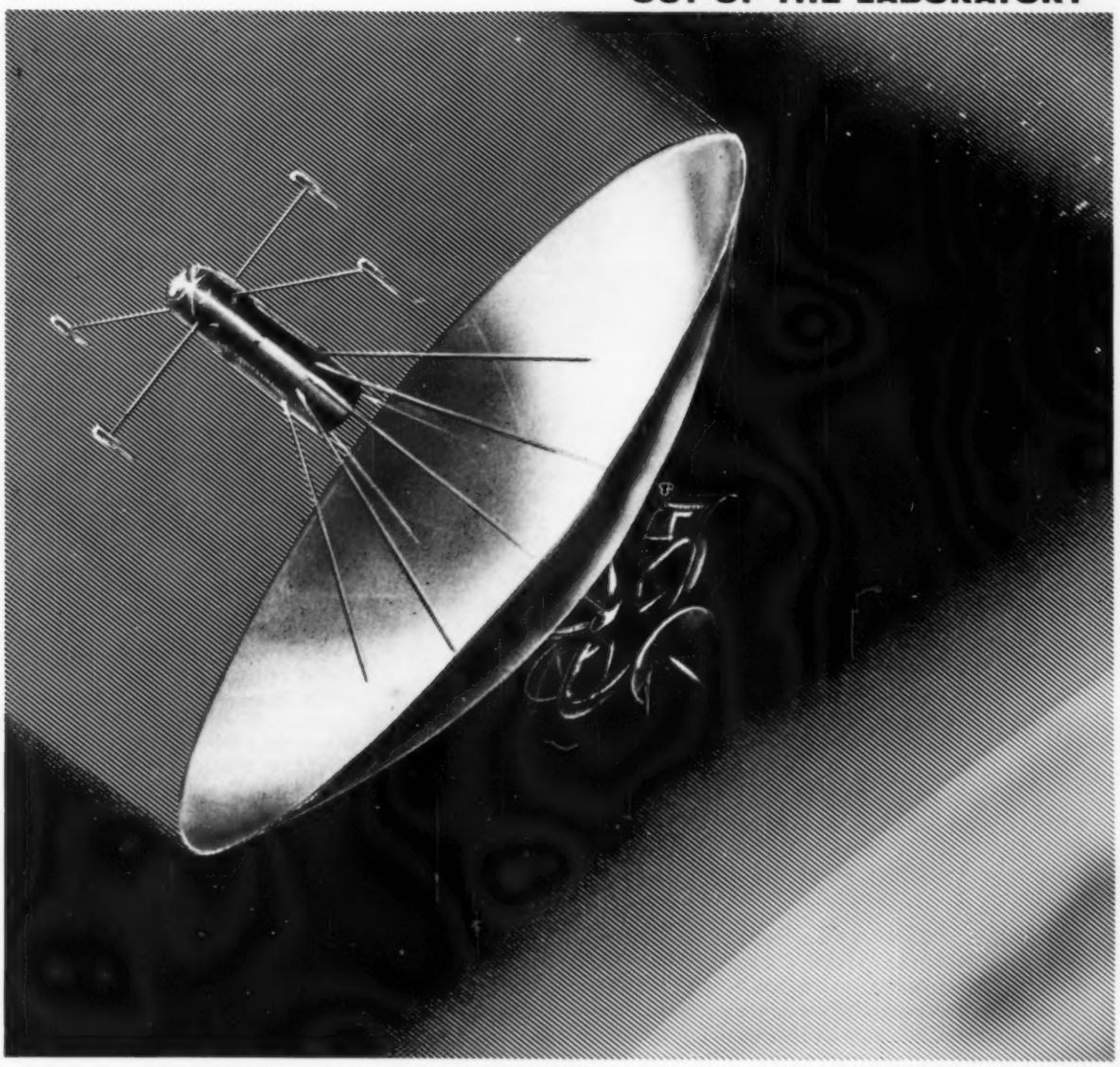
Trendletter

Sir:

Your Research Trendletter (in Vol. 3, No. 2) indicates a great need for the widespread dissemination of concise

NO. 32 IN A SERIES

OUT OF THE LABORATORY



Advanced power conversion systems for space vehicles utilizing energy of the sun or heat from a nuclear reactor are now being developed by Garrett's AiResearch divisions. Under evaluation are dynamic and static systems which convert heat into a continuous electrical power supply for space flight missions of extended duration. Component and material developments for these systems are being advanced in the fields of liquid metals, heat transfer, nonmechanical and turboelectric energy conversion, turbomachinery, alternators, and controls — vital contributions by Garrett to the conquest of space.

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Prof. John A. Wheeler's theory of lines of force in curved space-time forming physical geometrodynamic patterns, as noted in The New York Times of April 21, 1961, marks one of the greatest scientific advances of this century.

In support thereof, I cite my copyrighted essay, "God's Circle," published in May, 1953, wherein it is disclosed that the cosmic creative process is based on the circle or curved portion thereof and is manifested by alternate members or half-cycles, and therefore of alternating polarity as the alternate members of half-cycles progress along a zero line (trapped line of force) in space-time. The evolution of the basic geometrodynamic life-form patterns on this planet are described therein.

From the point of view of space conquest it will be noted that there is a definite relationship between the alphabets and numerical system on our planet which are discrete segmental units of a circle or zero, and the other planets in the cosmos moving in the directional flow of time.

Time flows in a direction and is manifested by matter in the form of sine waves. Time also flows in an opposite direction, or backwards, with an inherent space interval functioning somewhat like a capacitor, of which the basic example is the transposition in algebraic equations to find values or interpretations which, at the outset, are unknown. Prof. Nikolai A. Kozyrev of the U.S.S.R. Academy of Sciences advanced this theory six years after the publication of my essay, and it is more than probable that the Russians have applied this theory to attain greater thrust for their rockets.

Harry B. Fuchs
Jamaica, N. Y.

Management machines

Sir:

We were delighted to see "Management Machines—A System Approach" (Vol. 3, No. 1) by Dr. Allen Rowe, since we had a very personal interest in it in its formative stages. Dr. Rowe was affiliated with us when the article was prepared.

W. A. Johnston
System Development Corp.

Reliability

Sir:

In "Feedback" in Vol. 2, No. 6, regarding the reliability articles in the previous issue (Vol. 2, No. 5), George H. Scheer, chief, basic techniques branch, Communications Laboratory,

WADD, noted that the design engineer will become more and more a reliability engineer. He stated, "Reliability must be introduced in the earliest stages of development and carried through operational life."

We need more basic articles covering all phases of quality engineering, which includes quality assurance, reliability, quality control, value engineering, certain phases of operations research, standardization, inspection, test, evaluation, design of experiments, and decision-making functions.

As you see from this list, the designer must know what market is being covered to design properly any product, commercial or military. There are so many aspects to the problems that must be covered that we find usually more than 50% of the important items not covered.

Harry G. Romig
Senior Scientist
Operations Research Inc.

Editorial advisory board

Sir:

I am still reeling from the impact of your last issue which named your new Editorial Advisory Board members. Whatever legerdemain you used to assemble such a distinguished group must certainly become a classic story in the history of publishing.

I have watched the progress of Industrial Research with interest and am delighted.

Ted Pittenger
Fletcher Richards, Calkins & Holden Inc.

Can readers help?

Sir:

Enclosed please find a section of what we consider a typical knife used in a three-roller ink mill. This knife is held in a suitable adapter and is intended to remove the already processed ink from the surface of a three-roller mill roll. In practice, these rolls revolve at about 350 rpm with a typical roll size being 16" in diameter and 40" working length. The particular blade sample which we sent you was used in a roller mill for approximately four hours and, if you will look at the face opposite the code number and examine the working edge under approximately 10 power magnification, you will note alternately depressed and raised areas in the cutting edge.

For many years our company has been trying to solve the problem of early failure in roller mill blades where the roller mill is being used for printing ink. (It should be said that this is not so serious a problem with paint manufacturers that use substantially the same device but differs in that they

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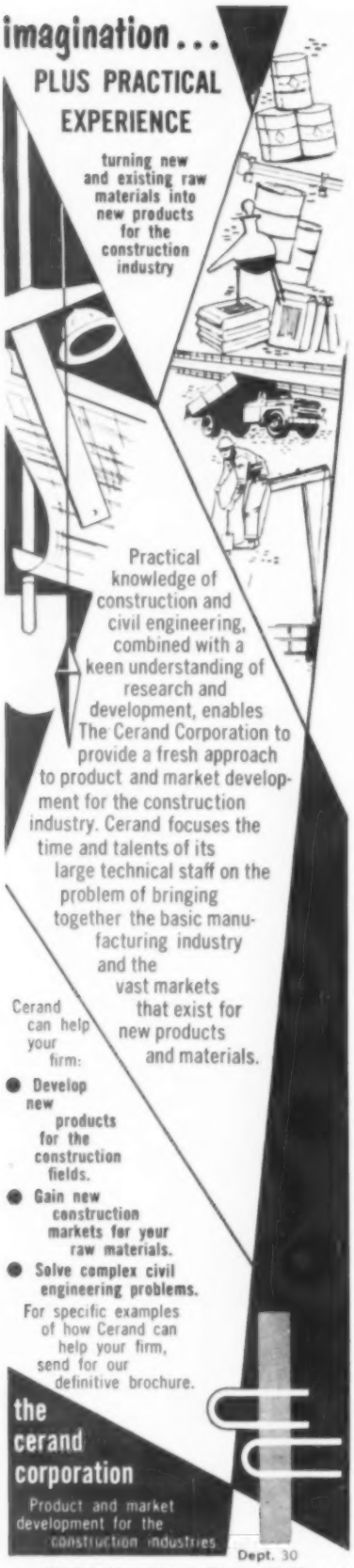
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process material, which has a much more abrasive character than does printing ink.)

The problem is basically one where, due to the failure of the cutting edge to remain linear, a considerable quantity of material that already has been processed properly is recycled with a consequent loss in efficiency for the entire process. Additionally, the mill blades cost from 50 cents to $1 each, and it requires a minimum of 30 minutes down time to replace the blade. Practically, we find it necessary to replace this blade at least daily, if not more frequently. Our purpose, therefore, in writing to you is to determine if there is an area in which you may be able to help us solve this problem.

Werner F. Gerlach
Superintendent
Capitol Printing Ink Co. Inc.

Sir:

A short time ago, I read the following comment: "Sam the Rhesus monkey survived the trip he took in space in his Little Joe Capsule; this was made possible by a film of 'Thermo-Lag Compound' sprayed on the outside. This film kept the internal temperature at a comfortable 90 degrees, although air friction heated the outside to more than 2,000 F."

I am interested in obtaining further information about this "Thermo-Lag Compound," who makes it, something of its makeup, properties, cost, etc. I have made numerous inquiries of chemical companies about this compound but without success. No one seems to be familiar with "Thermo-Lag." Can you help me?

Roy R. Graves
Real Fresh Milk Inc.

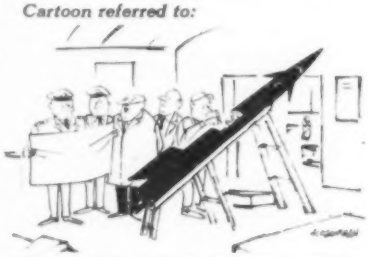
Cartooncomment

Sir:

Your cartoon in the last issue is an antiantimissilemissilemissile, of course.

C. A. Youngdahl
Process Control Services Co.

Cartoon referred to:



"It's a guided missile to intercept the guided missiles the enemy will send up to intercept our first guided missiles."

Stimulus

Sir:

We are delighted with your book Stimulus, which contains reprints of I•R sections. It looks so intriguing that I have taken it home with me as a replacement for the evening paper during the last couple of nights.

Albert A. Kohler
President
Albert A. Kohler Co. Inc.

I•R borrowers

Sir:

I enjoy reading your extremely informative magazine very much. Scientific and technological advances are presented in an uncluttered, straightforward manner that even I, as a scientist, can appreciate.

I am tiring, though, of borrowing the magazine and have failed thus far at convincing my barber to subscribe to it for his customers. Therefore, you will find enclosed a check to cover a two-year subscription.

Sheldon Breiner
Palo Alto, Calif.

Sir:

Sincere congratulations on some mighty fine publishing. One of our clients is AC Spark Plug and we noticed your efforts on the desks we normally visit. After seeing quite a few issues, I've decided to subscribe. I can't keep swiping AC's books!

Joseph E. Boucher
Acorn Studio

Serendipity

Sir:

The ideas and applications displayed by Industrial Research are sensational, but no more so than the "eye catcher" hanging just above my boss's desk. It is a vivid black and purple design with the word "Serendipity" blazoned across it. I cut this picture from the back of your magazine some months ago (Vol. 1, No. 4), and framed it for our office.

Needless to say, this picture interrupts the most esoteric conversations.

Geraldine W. Werner
Secretary to Chief
Technical Evaluation Office
U.S. Army Research Office (Durham)

Sir:

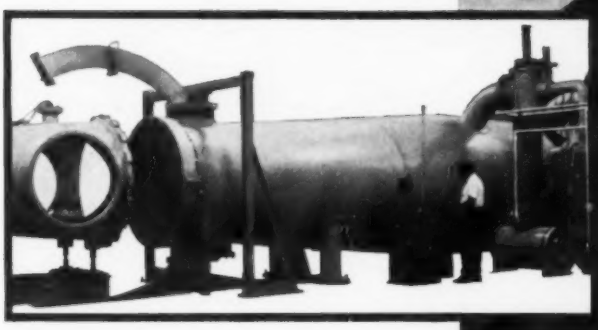
We have found the articles in your periodical interesting for the most part, and hope that they will continue to be so.

Charles Calderaro
Broadview Research Corp.

Sir:

Your fine magazine is enjoyably read by many members of our management.

Richard E. Booth
Assistant to President
Daystrom Inc.



THE EDGE OF SPACE IS IN ST. LOUIS

Years before McDonnell space vehicles reach the testing centers at Canaveral, designs are subjected to the severe environment existing at the edge of space. At McDonnell's Hypervelocity Impulse Tunnel in St. Louis the combined electrical impulse power of the Grand Coulee and Hoover Dams breaks loose into the confines of a cannon-like funnel and subjects space vehicle models to simulated altitudes up to 60 miles, 14,000° temperatures and speeds up to Mach 27.

From McDonnell's unduplicated aerospace facilities such as this come innovations; innovations that have characterized McDonnell products through the Company's 22-year history; innovations from forward thinking engineers who seek to shape air and space vehicles to their unique environmental requirements, rather than stretch existing designs to achieve marginal success. In the development of these advanced air and space systems, opportunities exist for advanced degree physicists, scientists and electronic management engineers anxious to take broad strides across the "State of the Art" barrier. Your inquiry is invited.

Write R. F. Kaletta, Engineering Employment
McDonnell Aircraft, St. Louis, Mo.

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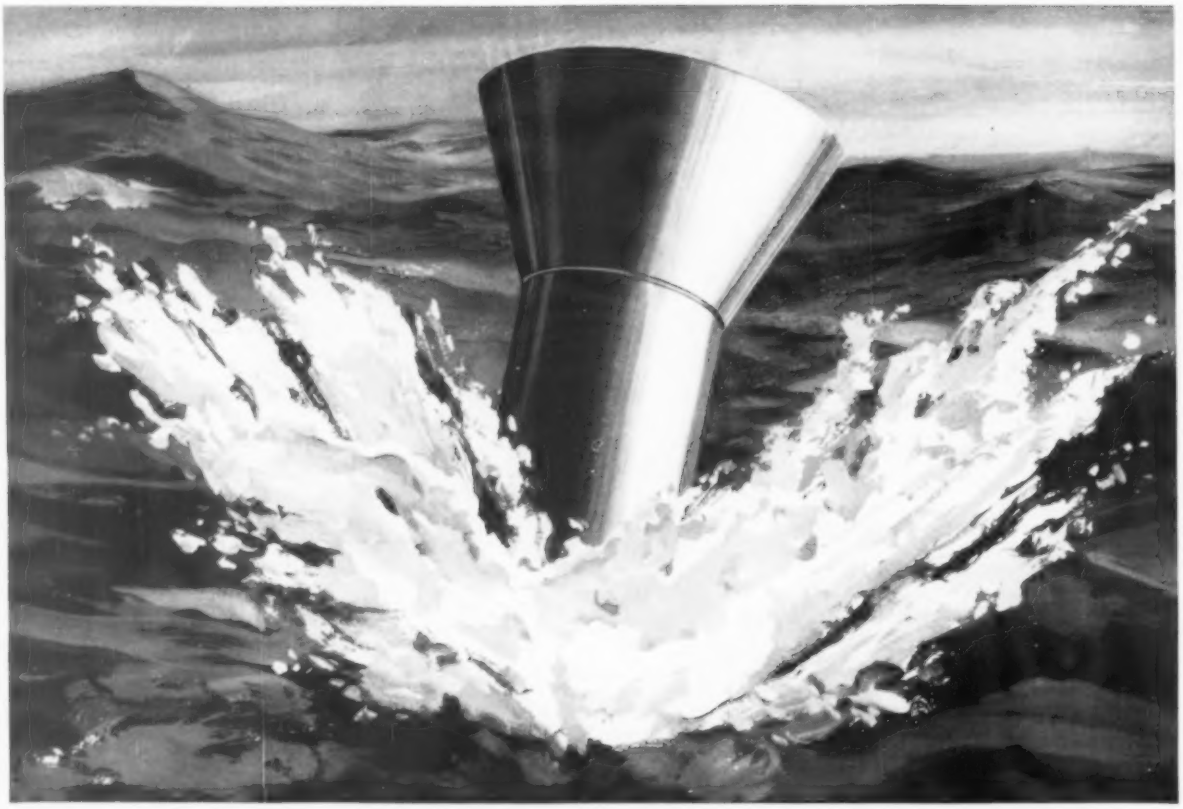

HOW THE OCEAN GREW "EARS" TO PINPOINT MISSILE SHOTS

A quarter of the world away from its launching pad an experimental missile nose cone enters its ocean target area.

How close has it come to the desired impact point?

Where actually did the nose cone fall?

To answer these questions quickly and accurately, Bell Laboratories developed a special system of deep-sea hydrophones—the Missile Impact Locating System (MILS) manufactured by Western Electric and installed by the U. S. Navy with technical assistance from Western Electric in both the Atlantic and Pacific Missile ranges. MILS involves two types of networks.

- One is a long-distance network which utilizes the ocean's deep sound channel. It monitors millions of square miles of ocean. The impacting nose cone releases a small bomb which sinks and explodes at an optimum depth for the transmission of underwater sounds. Vibrations from the explosion are picked up by hydrophones stationed at the optimum depth and carried by cables to shore stations. Time differences in arrivals between these vibrations at different hydrophones are measured and used to compute location of the impact.
- The other is a "bull's-eye" network that monitors a restricted target area with extraordinary precision. This network is so sensitive it does not require the energetic explosion of a bomb but can detect the mere splash of a nose cone striking the ocean's surface—and precisely fix its location.

The universe of sound—above the earth, below the ocean—is one of the worlds of science constantly being explored by Bell Laboratories. The Missile Impact Locating System reflects the same kind of informed ingenuity which constantly reveals new ways to improve the range of Bell System services.

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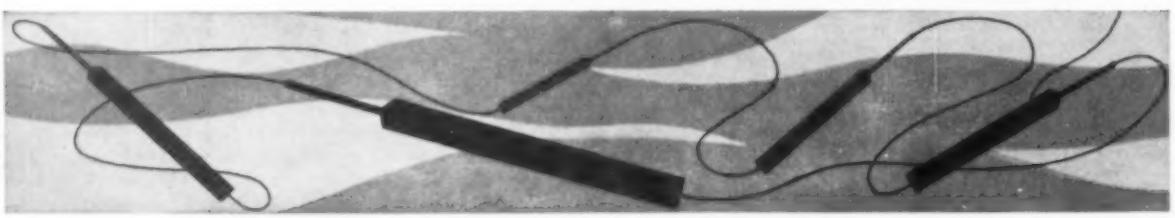


by **G. B. Whisenhunt Jr.,** *lead engineer, Vought Astronautics Div., Chance Vought Corp.*

LIVING IN SPACE

COMDR. ALAN B. SHEPARD JR. put the United States back into the space race on May 5 when he rocketed to an altitude of 115 miles in the world's first pilot-controlled spaceship. His feat, plus Russian Major Yuri A. Gagarin's orbit around the earth three weeks earlier, still proves only that it is possible to put a man into space. Until a life support system is developed to provide a livable environment for multi-man/multi-day missions deep into space, the ancient dream of manned space exploration remains unfulfilled.

Manned space missions of longer duration, bigger crews, and deeper penetrations into space are certain to follow. Within a few years, manned landings on the moon will be achieved. U.S. spacemen actually are gearing up for a lunar launch about 1969 or 1970. A second sub-orbital flight similar to Shepard's was to have been made by the time you read this; a third is scheduled for late summer; and the first orbit by a manned Mercury capsule is slated at the end of this year.

Research toward providing a livable environment for longer missions is only beginning. The answers to short duration survival in space—one man for a few hours—have been drawn primarily from experience with high-performance airplanes.

For flights of more than a few orbits around the earth, the problem of supplying man's environment has a major influence on the design and cost of the vehicle system. The Mercury program, for example, already has cost $400-million, twice the original budget estimate. Remaining tests and the anticipated orbital flights will cost another $100-million. Therefore, new and unique concepts in space vehicle life support systems and design techniques are needed to reduce the complexity and costs of manned space programs.

All the comforts of home

The primary requirement of a life support system is to provide man's inputs, process or store the outputs, and control the environment of the space cabin within certain limitations. For missions exceeding 24 hours, these functions must be accomplished without pressure suits or other apparatus restricting the astronaut's body. In other words, the normal environment within the space cabin must be suitable for man to perform his functions while dressed in normal flight clothing.

The tables below provide an insight into the magnitude of the life support problem. Man's daily balance can be expressed as:

AVERAGE INPUT	POUNDS
Food	1.2
Water in food	1.9
Water in drink	3.2
Oxygen	2.0
TOTAL	8.3

AVERAGE OUTPUT	POUNDS
Fecal solid	0.2
Vapor as sweat	1.5
Vapor as breath	0.8
Liquid as urine	3.3
Liquid as fecal	0.3
Carbon dioxide	2.2
TOTAL	8.3

Thus, the environment of a manned space cabin must be controlled within the following limits:

- *Oxygen*—partial pressure main-

WHEN ASTRONAUTS *can move freely in space, their air supply likely will come from an individual atmosphere control unit such as the "Chemacon Backpack" developed for the Navy by MSA Research Corp.*

tained near 2.8 psi (normal oxygen concentration at sea level).

- *Carbon dioxide*—partial pressure maintained below 1% of total atmosphere.
- *Inert gas*—sufficient concentration to maintain total cabin pressure of five to 14.7 psi.
- *Humidity* — relative humidity maintained between 40 and 60%.
- *Temperature* — maintained between 70 and 80 F, including heat removal of 12,000 BTUs per day per man, or 1/12-ton of air conditioning per man.
- *Water vapor*—2.3 lbs. per day per man to be removed from cabin atmosphere.
- *Waste*—3.3 lbs. urine, 0.3 lbs. fecal water, and 0.2 lbs. fecal solid to be removed per day per man.
- *Odors*—toxic and noxious, to be eliminated from cabin.

The need to breathe

Although man can adapt to his environment in many ways, he exhibits little natural flexibility in meeting his respiratory needs. An adequate amount of oxygen must be made available to an astronaut to keep him breathing, but a relatively wide tolerance in compartment pressure is acceptable. Design considerations for specific vehicles are vehicle weight, hazards (fire and meteoroids), power requirements, and effect on human performance due to deviation from the earth's natural environment.

Waste heat generated by the astronaut and by equipment within the vehicle must be ejected to maintain required temperature limits. The vacuum of space requires that all heat exchange between the ship and its surroundings be accomplished by radiation only. On short duration missions, such as Gagarin's or Project Mercury flights, it is possible to use an expendable coolant stored in the vehicle prior to launch. With this concept, waste heat is transferred to an expendable coolant and vented to space.

For mission durations of more than about 24 hours, however, the weight of expendable coolant becomes excessive and heat dissipation by radiation to space becomes more economical. The significance of low-weight components is apparent when considering that it costs approximately $10,000 to put one pound of payload in a near earth orbit with current booster systems.

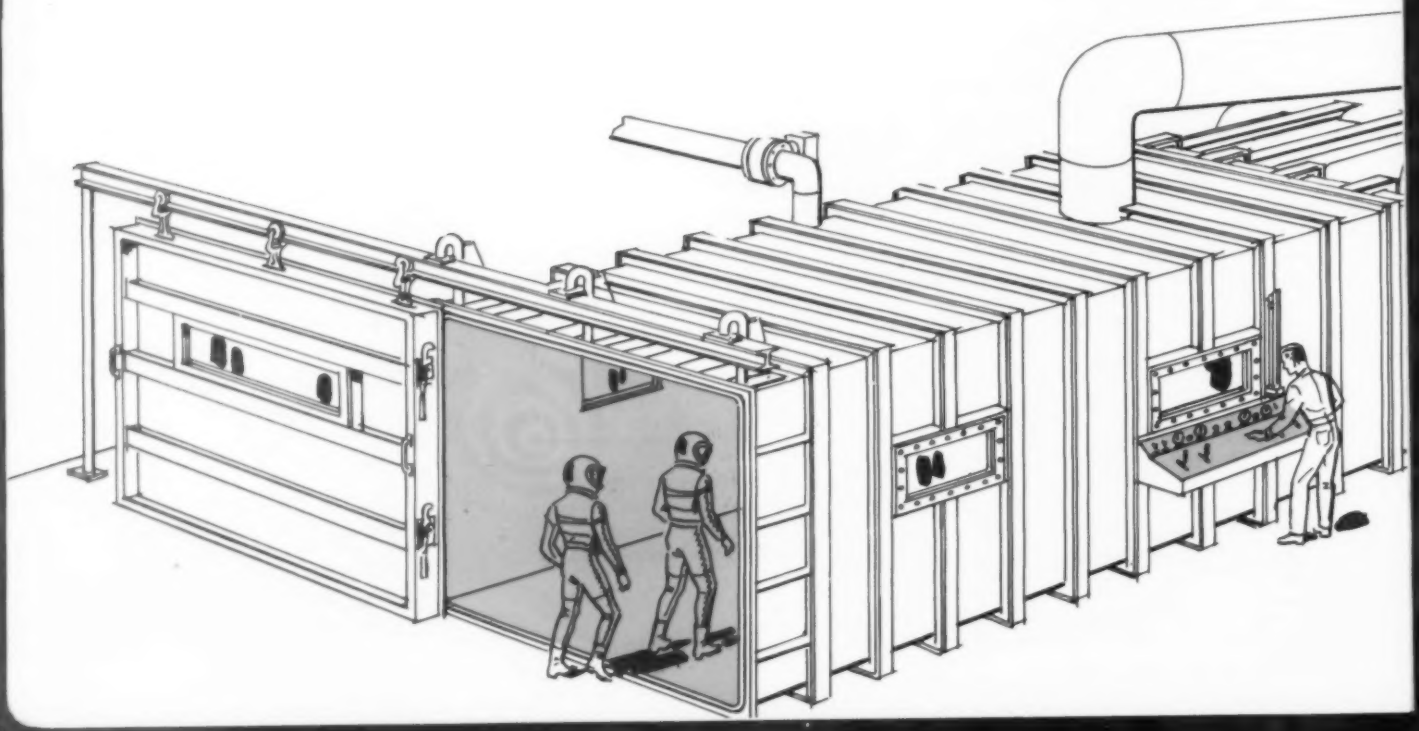
SPACE ENVIRONMENTAL *chambers, such as Republic's "mousetrap" (above) and the high altitude facility being built for Boeing by Vacudyne Corp. (below), enable scientists to simulate conditions encountered in outer space. The mouse's reaction to altitude increases is being measured here. Boeing's new chamber will make it possible to simulate altitudes beyond 200,000 feet for the first time in a laboratory.*

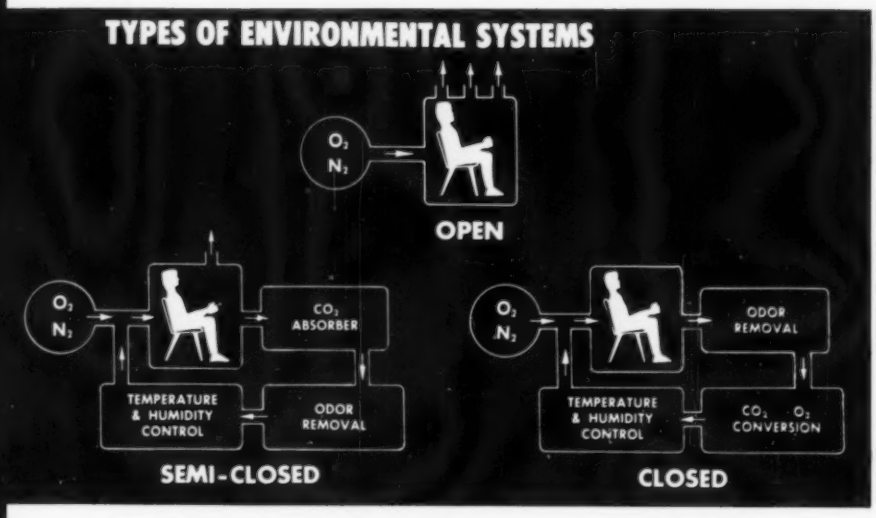
Reliability = survival

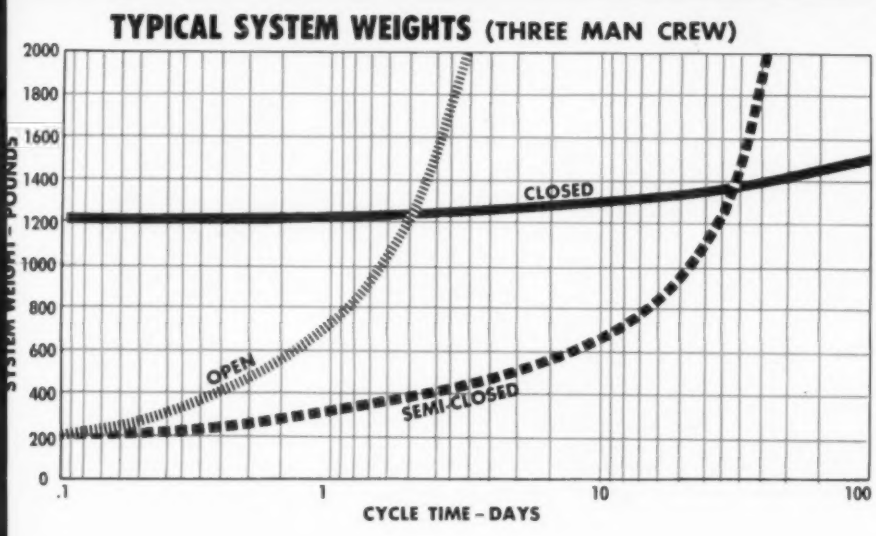
Perfect functioning of the life support system throughout the complete mission is mandatory for crew survival. There can be no bailing out should equipment fail; the velocities required to remain in space produce sufficient kinetic energy to vaporize the escapee when reentering the earth's atmosphere. Long operating times without equipment failure must be built into the system. Such reliability can be accomplished by simplicity of design, redundancy of critical components, and utilization of the crew for in-flight repair. Achieving the required system reliability is the greatest problem facing life system designers.

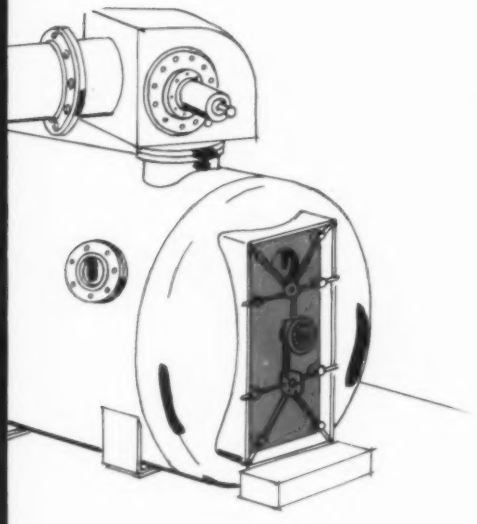
Depressurization is another hazard. Meteoroid peneration might not wreck the ship, but would result in rapid loss of pressure within the cabin. Separate sealed compartments like those found on ships and submarines could protect the crew during long flights. The crew could retire to a sealed compartment, don pressurized suits, and return to repair the damaged compartment.

To help man probe further into decompression problems to be encountered in space, a high-altitude chamber with explosive decompression features (see below) being built









Since joining Chance Vought in 1955, G. B. Whisenhunt has worked primarily on the analysis of environmental, secondary power, and engine fuel systems. Responsible for the environmental system design studies for a manned lunar vehicle, he also helped develop a method of analog simulation for environmental systems analysis. Whisenhunt currently is analyzing atmospheric systems for space vehicles. He received his MS in mechanical engineering from Texas A & M.

for Boeing by Vacudyne Corp., Chicago. Instantaneous loss of cabin pressure will be simulated within the facility to test special equipment used in space vehicles. The space chamber also will help train personnel and acquaint them with some of the potential hazards of space flight.

Altitudes above 200,000 feet as well as 250 feet below sea level can be simulated in only 15 minutes with the space chamber. One of the largest of its kind, the altitude chamber will have a main compartment 10 by 22, by 8 feet high, in which 10 test subjects can be indoctrinated simultaneously. It will withstand various humidities and temperature conditions ranging from minus 40 F to plus 220 F.

The radiation hazard

Radiation belts surrounding the earth also present significant hazards to man in space. The earth's radiation belt can be tolerated without shielding in orbits below approximately 300 miles and by rapid movement through the belts for lunar and planetary missions. Although the weight penalty for shielding against radiation is tremendous, adequate shielding techniques will be required for planetary missions.

Inadequate shielding can be as dangerous as no shielding at all, even if exposure rates to radiation particle bombardment are sub-lethal, studies by North American Inc.'s Space and Information Systems Div. have shown. The space radiation belt can be as crippling to the spacecraft as it is lethal to man, according to Orval H. Minney of North American, who has analyzed effects of radiation on electronic, life support, and human components of a hypothetical space system. And exposure to continued so-called "safe" radiation levels will produce judgment errors that could result in mission failure.

Solar flares also can result in radiation levels sufficiently high to permanently injure or kill unprotected crew members within a few minutes. More accurate data on the cycles of these flares and methods to predict their occurrence are required so that manned space shots can be scheduled during periods of low solar activity.

Concepts for survival

Basically, three types of systems have evolved to provide man's environment in space: open, semi-closed, and closed (see diagram at top).

The open system, similar to that now used in high-performance aircraft, depends on leakage to remove gaseous waste products.

Both semi-closed and closed sys-

tems are based on minimum leakage. In the semi-closed system, however, waste products are removed from the cabin and stored or ejected overboard. In the closed system, waste products are converted into required supplies and reused.

An approximation of the weights of these three systems for a three-man crew is shown in the chart on p. 21. Of course, a completely open system will be possible only for short flights of one or two hours. The semi-closed system is the lightest weight method for mission times of a few hours to approximately four weeks. For mission times in excess of about 12 man-weeks (three men for four weeks), the closed system provides the lightest approach. Closed system studies still are in their infancy, but future research and optimization may reduce or increase mission times such that closed systems become practical.

Since the open system is suitable for one or two orbits, it will have primary application in ships shuttling equipment and cargo between the earth and nearby space stations. The open system is most feasible for a spaceship designed for a single orbit, such as the Gagarin flight. Semi-closed systems will be required for space laboratories, temporary space stations, circumlunar ships, lunar landing ships, and other vehicles remaining in space for medium durations, such as the Apollo concept currently under study by the NASA.

A permanent space station and a lunar base are the first space missions in which a closed environmental system is desirable. Since both stations could be supplied from earth on a periodic basis, development of a closed life support system is not mandatory for mission accomplishment. From the logistics standpoint, however, a closed system is a good idea.

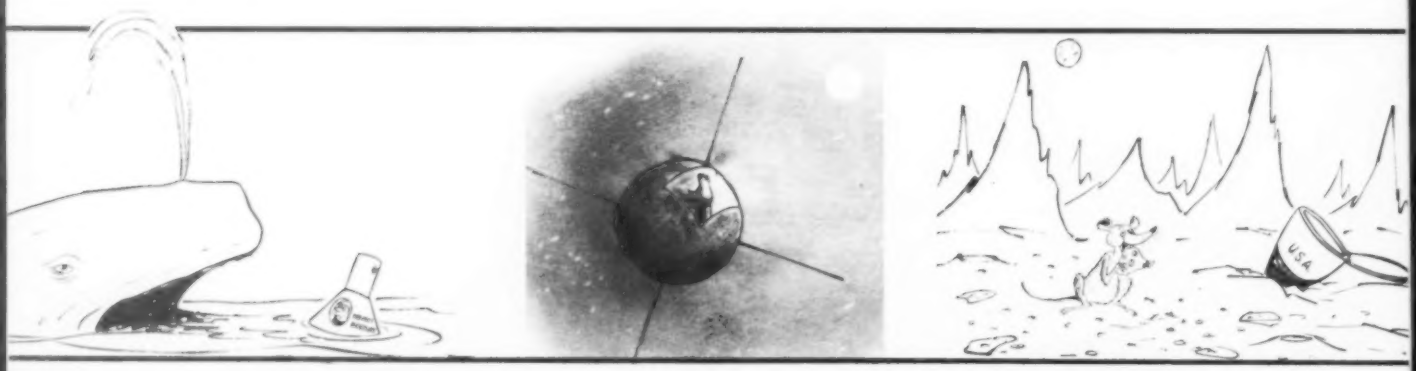
Interplanetary travel will require closed life support systems in which all waste matter is converted into required supplies for reuse. The conversion will include oxygen from carbon dioxide, potable water from urine, and food from plant or animal life fed by feces and other waste material.

Care and feeding of spacemen

Boeing Aero-Space Div. scientists already have proved that man can live fairly comfortably in space by using oxygen produced by plant life. They conducted an experiment in which a man spent several hours in a

CONCEPTS FOR SPACE VEHICLE LIFE SUPPORT COMPONENTS

Life Support Function	Open System	Semi-Closed System	Closed System
Cabin atmosphere storage techniques	High pressure gas Liquid Chemical Combinations	Same as for open system	Emergency supplies —storage. (Same as for open system) Primary supply by conversion of carbon dioxide to oxygen & carbon
Carbon dioxide removal techniques	Leakage of cabin gas	Chemical absorption Adsorption (molecular sieve) Diffusion by permeable membranes Freezeout New developments	Conversion to oxygen by: photosynthesis electrolytic decomposition photolysis new developments
Humidity control	Leakage of cabin gas	Chemical absorption Adsorption Condensation & collection New developments	Condensation & collection for reuse
Temperature control	Expendable coolant Chemical decomposition	Radiation to space	Radiation to space
Odor & obnoxious gas control	Leakage of cabin gas	Chemical reaction Activated charcoal Periodic changing of cabin air	New developments required
Sanitation	None required due to short duration of mission	Refrigeration & storage of waste Overboard ejection	New developments required
Food and water	None required due to short duration of mission	Provided by initial stores	New developments required



sealed chamber breathing oxygen supplied by green algae. A monkey was kept alive and healthy in a sealed room by breathing oxygen produced by plants for 50 hours at a time in other experiments at General Dynamics' Electric Boat Div., New London, Conn. Algae also can provide a source of space food.

In a project for the Air Research & Development Command, research men at Battelle Memorial Institute are designing a system to convert an astronaut's breath into breathable oxygen. A prototype has been built to convert carbon dioxide into water as a major step in developing a complete oxygen recovery system. Water vapor and solid carbon are produced by a reaction between the carbon dioxide and hydrogen over a heated catalyst. The condensed water vapor will be fed to an electrolytic cell, where it will be broken down into oxygen and hydrogen.

Efficient methods of reusing human waste to grow food and provide pure drinking water have been developed by Boeing and General Electric's Missile & Space Vehicle Dept. The problem remaining is how to reduce the weight of the recirculatory system so it can be used in a space vehicle.

On another tack, chemical injections to increase the body's tolerance to carbon dioxide are being investigated at Columbia University Medical Center, New York. This added resistance would be a vital factor if the air system in the space capsule were to fail.

Ultimate goal of all this experimentation is the creation of a packaged closed circuit environment for space travelers. However, a completely closed system is difficult to imagine even when the weight penalties for extended missions are assessed. The best closed systems man can build will have some dead ends where waste products can be used no further.

Combining concepts with components

A varied assortment of components is required for the many life support functions of a manned space system. Some of the present concepts are shown in the chart on p. 22. Many of the approaches indicated—for instance, conversion of carbon dioxide given off by the crew to usable oxygen and carbon—currently are in the idea stage and require proof of principle and considerable study before they can be used in actual vehicle systems.

The significance of a proven method for the conversion of wastes is obvious when weight penalties of storing sufficient oxygen for the crew of an interplanetary space vehicle are considered. For a three-man, two-year mission, oxygen weight alone amounts to some 4,380 lbs. Adding the weight of storage containers and provisions for oxygen boil-off or leakage increases the weight penalty beyond an acceptable value.

An examination of the many components listed in the chart on page 22 shows that a great number of systems can be assembled by various combinations of these components, making the task of system selection for a specific vehicle difficult. While it is true that many approaches can be eliminated by inspection, many other components must be evaluated —both as individual components and on a system basis—against carefully selected design criteria. These criteria include weight reliability, development status, flexibility (suitability for varied mission requirements), power requirements, and cost. The importance given to these different criteria is determined from the mission objectives and from specific vehicle characteristics.

Final system selection

Final system selection requires evaluation of the most desirable components on a system basis. In order to achieve the optimum overall vehicle design, the evaluation must include other than life support systems, such as auxiliary power, propulsion, attitude control, and equipment cooling systems.

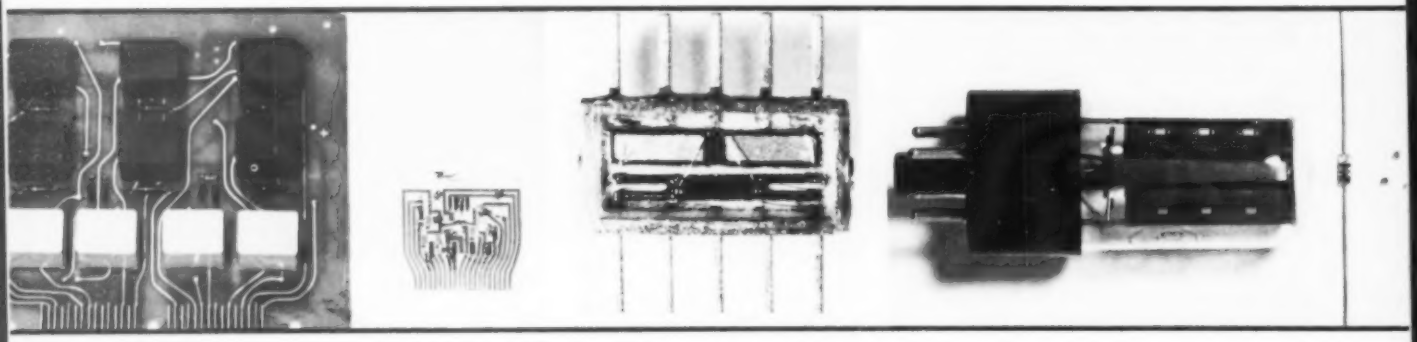
Inclusion of the other vehicle systems allows integration of functions so that all available energy is utilized to the fullest extent. For example, oxygen boil-off from a liquid oxygen propulsion system can be used for breathing; water obtained from combustion in a hydrogen-oxygen auxiliary power system can be purified and drunk by the crew.

Construction of the many different systems and components to get actual test data is desirable but expensive. Often the systems can be simulated on an analog computer, expressing functions of the system as mathematical equations. From these equations, analogs are constructed to simulate the operating characteristics of each component. These analogs, then, provide blocks from which systems may be put together and system performance data obtained.

Analogs allow the changing of components, control procedures, and operating variables with minimum effort. For example, a simple change in the analog will show the effect of different cabin pressures, leakage rates, controls, control settings, temperatures, airflows, cabin volumes, crew activity levels, etc. Thus, the most desirable components, control procedures, and system operating levels can be chosen.

In addition to computer simulation, biochemistry, bioengineering, radiation physics, and air conditioning, many other disciplines and interrelationships of science must be tapped to enable man to live outside of his fish-bowl atmosphere. New components, new materials, new food products, and even a new psychology will be required before man can live in space. ■

the MOLECTRONICS EN



by **Harrell V. Noble,** *electronic technolog*

THOUGH NOT IN THE DICTIONARY, molectronics* promises to usher in a new era in electronics—an era highlighted by extreme miniaturization and potential long life.

The hundreds of parts now used in electronic equipment will be replaced in the future by a few bits of solid state material. The molectronics engineer will need training in electronic circuits, physics, solid state physics, and physical chemistry, plus a considerable amount of engineering genius. He will know how to handle atomic and molecular properties to accomplish electronic functions such as amplification, oscillation, and tuning.

Generally, today's electronic technology requires three distinct types of electronics engineers. The components engineer designs the electron tubes, transistors, coils, tuning capacitors, and other parts so that they possess a wide variety of more or less standard characteristics. The components must meet all needs and also serve as building blocks for a second type of engineer—the equipment engineer.

The equipment engineer assembles and properly connects the right combination of these parts to make such things as a radio receiver, a transmitter, or a radar. He cares little about the physical or chemical make-up of the parts he uses. His primary concern is with the electrical characteristics of the parts and stability or controllability of such characteristics with time and changing environments.

The third type is the systems engineer who integrates compatible pieces of equipment into a complete and effective electronic system. For example, a communications system might include antennas, receivers, transmitters, power supplies, recorders, encoders, decoders, etc.; it would be the systems engineer's job to see that these items work together properly.

Tomorrow, a 'molecteer'

Tomorrow's molectronics engineer at least will be a combination of today's components engineer and equipment engineer, and in time will assume duties of the systems engineer as well. The reasons are obvious when you consider that the molectronics engineer designs a complete audio amplifier into a space of about 1/500th of a cubic inch. A conventional amplifier requires two radio tubes, dozens of resistors, capacitors, and other parts, each of which probably was constructed separately by different manufacturers. Conventional parts then are connected by wires and mounted on a metallic chassis. Occupying a space as large as 5″ x 5″ x 2″, or 50 cubic inches, the conventional amplifier is 25,000 times larger than an equivalent molecular amplifier. However, at the completion of the conventional assembly, each part is still identifiable and can be disconnected, removed, and placed in another assembly.

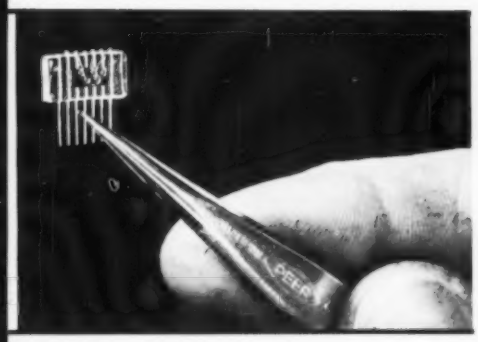
Amplification in a block

With today's technology, the equivalent molectronics amplifier might use a 1/4″ x 1/16″ x 1/100″ semiconductor for the chassis. On this silicon or germanium substrate, various passive or active regions are deposited, diffused, alloyed, or plated to serve as resistors, capacitors, and transistors—but which cannot be disassembled for use elsewhere. The unit then is encapsulated by a thin coating of plastic or glass to protect it. When completed, the amplifier is a solid structure providing amplification in a single block called a "FEB" (Functional Electronic Block).

A radio receiver can be made up of a number of FEBs such as a radio frequency amplifier, oscillator-converter, intermediate amplifier, and detector-audio amplifier. Since each FEB is quite small and possibly can be fabricated on the same substrate, it is expected that a complete radio

**Mo'·lec·tro'·nics (n.) Derived from the Air Force term, molecular electronics. Tailoring of the molecular properties of matter to perform electronic jobs.*

GINEER–a new species



BENDIX, TEXAS INSTRUMENTS, *Hughes, and Westinghouse all are working in molectronics. The photos (left to right) show Bendix' thin film two-dimensional miniaturization of multi-function circuitry compared to same circuitry using modular techniques and conventional components; TI's silicon multivibrator mounted on a header only ¼ by ⅛ inch in size; Hughes' microseal component package for a complete transistor or diode structure, occupying only a fraction of the allowable space recommended for microminiaturization; an early model multiple diode gate now undergoing streamlining at Westinghouse to reduce the size of the transparent encapsulant; and (below) Westinghouse' molecular diode gate compared to a transistorized unit, with card insert and complete computer unit in background.*

boratory, Wright Air Development Div.

receiver (less batteries, antenna, and speaker) eventually could be made in one solid block about the size of a postage stamp and perhaps an eighth-inch thick.

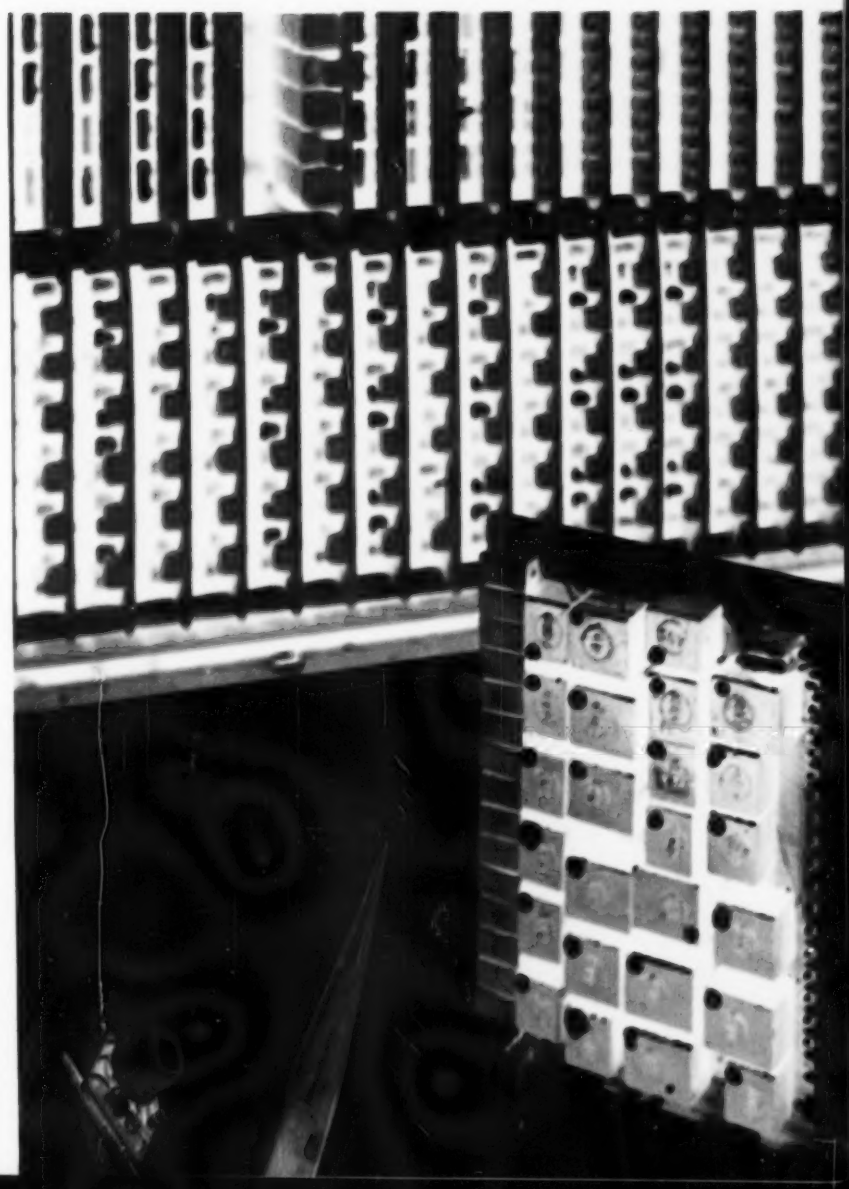
How did all this begin? There were many beginnings. One of them, for this writer, started in the early 1930s on a project to make a narrow band audio amplifier — a 20-cycle band width in the frequency range of 20 to 200 cycles. Such an amplifier already was in use but it employed iron core inductances and capacitors to provide band pass characteristics and it weighed several pounds.

A magnetostrictive answer

The solution to this particular problem used the mechanical resonance characteristics of metallic rods made of magnetostrictive material. A magnetostrictive material is one that changes in size or shape when subjected to a magnetic field; conversely, when such a material is stressed, it changes its magnetic characteristics.

The filter consisted of a centrally mounted nichrome rod (a magnetostrictive material) with a coil around one end for the input signal which magnetically stressed the rod, plus a coil around the opposite end which converted the stress transmitted into an electrical voltage. Only when the input signal is at or near the mechanical resonance frequency of the rod is the stress transmitted well to the output coil. By using a magnetostrictive filter the weight was reduced to about a pound.

A similar filter using bars of piezo-



electric materials also was made. In a piezoelectric material an electric field produces a material stress, and a material stress can produce a voltage. Here again the material stress is transmitted from one end of the material to the other, at or near the mechanical frequency of the piezoelectric bar. (Diagram 1 shows the electrical circuits for each type of filter.)

In these ways a rather complex electronic band-pass filtering function was accomplished by using the fundamental properties of matter.

In 1953 I began formulating plans for improving overall reliability of Air Force electronics. Diagram 2 illustrates the increasing number of electronic component parts used by the Air Force. It is obvious that reliability decreases as the number of parts increases (unless standards for individual parts are raised). And the improvements made during the last decade have not provided the necessary requirements for completely dependable systems.

Planning breakthroughs

In an effort to find a fresh approach, Air Force personnel visited several leading industrial organizations. Although few understood the needs outlined, several contracts of a broad nature were placed with the hope of achieving a breakthrough.

Unfortunately, breakthroughs cannot be scheduled. But in early 1958 we evolved a long-range program, called Composite Molecular Electronics, to create a favorable environment for future breakthroughs. A major part of this program involved cataloging all known electronic materials and the description of their properties. At this writing, 150 different characteristics have been identified and cataloged.

Some of these characteristics are associated with energy transfer. For example, the electromagnetic to electric family includes the photovoltaic effect, the photoconductive effect, and the photoelectric emission effect. These effects deal with the influence of light waves to the generation or control of electrical power. Other effects, like the Seebeck and Peltier, are concerned with the use of heat to produce electrical power directly or electrical power to produce a cooling effect. The piezoelectric and magnetostrictive effects involve mechanical to electrical energy conversion.

The research, development, and manufacture of transistors and diodes have advanced the state-of-the-art in semiconductors immensely; it is semiconductors on which the new technology, molecular electronics, primarily is based. In the future we can expect many combinations of effects to produce the functions we need.

Both Westinghouse and Texas Instruments offered a significant portion of their resources to the Air Force for an immediate exploitation of their semiconductor capabilities for developing electronic subsystems using FEBs. These offers were conceived independently and in 1959 contracts were placed with each company. Progress since then has been excellent.

In addition to significant size reduction, semiconductor devices should have increased life expectancy—or, from the military viewpoint, be extremely reliable. The reason is that most semiconductor materials and processing techniques will continue to be used as in transistors, which proved better than tubes in many applications. Further, the great reduction in the number of parts used in a complete system also reduces the number of inter-connections—always a great source of trouble for the manufacturer as well as the user.

For example, in one weapon system using about 100,000 parts and 250,000 inter-connections the numbers might be reduced as much as 1,000 to one.

Although early molecular items will cost several times more than conventional items, their reliability and reduced maintenance in military use should lessen the disadvantage. Frequently the overall yearly maintenance cost of current military electronic equipment is in excess of five times its original cost. With a potential operational life of five to 10 years, the initial cost becomes relatively unimportant, and molecular equipment could represent a savings over the long run.

The reduction in size and weight is also important for high-performance Air Force systems and spacecraft. The ratio of airframe and fuel

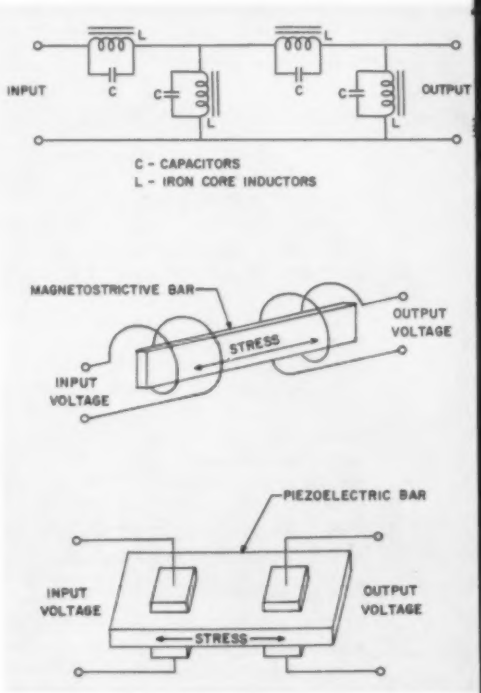


DIAGRAM 1 *shows electric circuits for band-pass filtering functions using fundamental properties of matter.*

As technical director of Wright Air Development Div.'s electronic technology laboratory, Harrell V. Noble is responsible for applied research directed toward timely and effective advancements in the state-of-the-art of basic electronic elements for future weapons systems. Prior to coming with the Air Force he spent 17 years in industry as R & D engineer on electron tubes, communications, radar, and guidance equipment. A Purdue graduate, Noble is a registered professional engineer and a Fellow of the IRE.

weights to payload weights may run as high as 1,000 to one. Thus if one pound of molecular equipment were to replace 1,000 pounds of today's electronics, the savings in missile weight would run into many expensive tons, and be more than enough to pay the cost of molecular equipment, to say nothing of increasing missile performance. Further, its small size would permit and encourage redundancy, thereby enhancing overall system reliability.

The question often is asked:

"When will molecular electronic devices appear on the market and what will be their impact on conventional technology?"

We can begin to see some equipment usage within three to five years. Some believe the military will have to establish confidence and encourage use of FEBs by reducing their cost, or making them available in sufficient quantities for widespread distribution to equipment designers. In the early development of transistors such methods were used with gratifying results. Except for those few FEBs which would have broad and repetitious usage, such as computer elements, it would be difficult for either manufacturer or user to pay for the design and pilot line runs needed to establish performance parameters. Military sponsorship and distribution to its contractors should make possible their use within this three-to-five-year period.

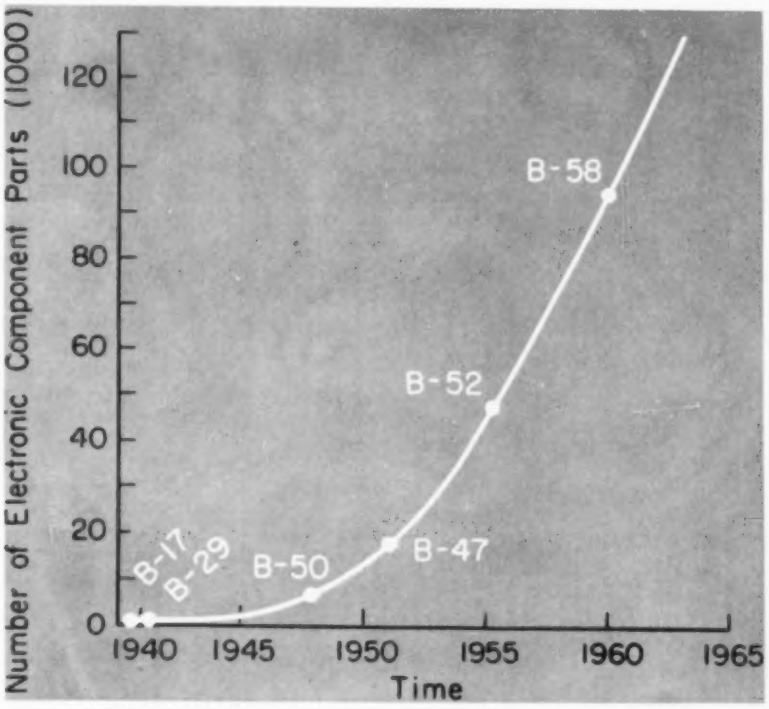


DIAGRAM 2 *indicates the trend of complexity of electronics in Air Force weapons systems during the last 20 years. As the number of parts increase, reliability decreases. This will continue unless standards for parts are raised.*

Devices now available

Westinghouse and Texas Instruments under Air Force contracts already have produced a number of different types of FEBs and some may be procured directly from manufacturers. FEBs now available include:

- *Amplifiers*—quartz parametric, d-c, low level audio, two-stage high level audio, three-stage high level audio, video, and voltage tuned (2.6 mc, 260 kc.)
- *Oscillators*—voltage tunable.
- *Switches*—multiposition three-terminal, multiposition two-terminal, and logic two-terminal.
- *Multivibrators* — cross-coupled bistable, tunnel-diode bistable, and cross-coupled astable.

The impact of molectronics on the electronics industry of the near future will be tremendous. The same structure that classifies engineers classifies industry. The manufacturer of individual components, the parts user who makes equipment, and the systems firm that combines electronic equipment all will see increased usage and sales of molectronic gear.

Semiconductor manufacturers should make the most immediate headway in molecular electronics. Their engineers already are familiar with semiconductor technology and have the basic know-how. However, they will have to establish circuit and subsystem organizations to determine exact performances needed in FEBs. Ordinarily such determinations would be made by equipment firms, and a series of industry combinations aimed directly at joining semiconductor technology with equipment manufacturers thus may result.

New combinations

Component manufacturers and systems engineering companies also may form new combinations as molectronic science advances and jockeying for position takes place.

Most fortunate are those few concerns now in the transistor, equipment, and subsystem business, which already possess most of the important skills needed. About a year ago, an informal survey was made of several companies with semiconductor capabilities to determine where they stood in the molectronics business. Several had changed radically from earlier positions and were seeking Air Force support in getting started.

The management of one large organization believed molectronics was the only way to lick the reliability problem, and either with or without Air Force support it planned to enter the field.

Several organizations had a wait-and-see attitude while a few doubted the feasibility of molectronics. However, one of these companies recently took an about-face position and now is actively engaged in the field—without Air Force support.

Molectronics appears to be gaining momentum rapidly. To be a real success in the next 10 years, every major electronic manufacturer, regardless of his present position, must assign a significant portion of his research, development, and manufacturing resources to this new field.

Needed: a 'versatile specialist'

Enthusiasm and interest has been indicated by a number of industry managements but one important element still is lacking—the combination of all necessary scientific know-how within single engineers. Such individual capability can come about first by working in teams of specialists and later through appropriate university instruction.

In spite of these roadblocks and delays, the "versatile specialist," the molectronics engineer, is certain to emerge. On his shoulders will fall the responsibility, vision, perspective, initiative, and the drive to expand, develop, and mature the new technology. ■

Cables manufactured by Reynolds Metals Company, Richmond, Virginia. Covering extruded of Tenite Polyethylene.

Why Reynolds covers these aluminum conductors with TENITE POLYETHYLENE

To obtain the highest possible performance from their secondary distribution and service line cables, Reynolds Metals Company chooses Tenite Polyethylene as a covering material.

Tenite Polyethylene is manufactured under as rigid a system of quality control as Reynolds' own aluminum conductors, and makes a tough, weatherproof, fast-stripping covering material which offers high dielectric strength and resistance to abrasion, heat, moisture, chemical attack and stress cracking. It remains flexible even at sub-zero temperatures and its light weight permits easy handling and wide spans. Users report that it gives long service life without festooning or splitting.

Tenite Polyethylene is easily extruded as jacketing or insulation for many diverse applications, from coaxials to control cables, from TV lead-ins to telephone wires. For a material with outstanding electrical, physical and chemical properties, specify Tenite Polyethylene. For further information, write EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, KINGSPORT, TENNESSEE.

Both natural and black electrical grade Tenite Polyethylene are available to cable manufacturers in a unique spherical pellet form which flows freely in the extrusion process and in "air-veying" of bulk shipments from truck to bin.

TENITE®
POLYETHYLENE
an Eastman plastic

THE RESEARCH TRENDLETTER

June-July, 1961

Dear Sir:

R&D aimed at direct conversion of energy to electricity is making significant gains toward providing new sources of power. A practical vapor thermionic converter with a 10-watt power output has been developed by General Electric's Power Tube Dept., Schenectady 5, N.Y. Advanced development in materials technology and in the technique of sealing the devices is cited by GE as the major solution to making a converter that will work in space environment without auxiliary cooling or typical laboratory control.

Prospects for commercial electric power generation through magnetohydrodynamics (MHD) have been advanced significantly with the announcement that 205 kilowatts of power have been produced in a new MHD generator at Avco-Everett Research Lab., 2385 Revere Beach Pkwy., Everett 49, Mass. This is 20 times greater than the power output achieved when the project was first revealed late in 1959.

Welbilt Corp., Maspeth, N.Y., has demonstrated a 1 1/2-cubic ft. thermoelectric refrigerator which it will produce in quantity next year. Other appliance makers have designed thermoelectric refrigerators, but none is in production because of high cost of materials. A tiny thermoelectric device that can boil or freeze a drop of water by using power from two flashlight batteries has been developed by Hughes Aircraft Co., 2020 Short St., Oceanside, Calif. Elements for the device were made by Jepson Thermoelectric Co., 139 Nevada St., El Segundo, Calif. Smaller than a paper clip, the device, used in clusters, could be applied to maintaining room temperature in a spaceship or operating an instant-defrosting refrigerator with no moving parts.

A portable thermoelectric generator capable of powering a transistor radio from the heat of a kerosene flame has been designed by Minnesota Mining & Mfg. Co., St. Paul, for use as a simple emergency power source. The generator will be used for operating radio sets in home fallout shelters. It also could be used in event of power failures caused by storms and in remote areas where electrical power is not available or battery supplies are limited. (See photograph No. 1.)

Dr. Frederick D. Sisler, U.S. Geological Survey scientist, has demonstrated a biochemical fuel cell that produces electrical energy directly from decomposing organic matter contained in ocean bottom sediments and sea water. Live algae also is a source of inexpensive supply of both oxygen and organic matter for fuel. A cell using algae probably could produce electricity indefinitely from solar energy alone, according to Sisler. Sewage is another potential energy source.

Energy conversion will be the subject of the entire next, October, issue of Industrial Research. This special reference edition will cover the state-of-the-art in each of the eight energy conversion fields.

aeronautics

Increased interest in aircars, near-ground craft that travel at very low altitudes, is evidenced in the announcement of a joint venture by Borg-Warner's Ingersoll Kalamazoo (Mich.) Div., and Avro Aircraft Ltd., Toronto, to develop and produce military vehicles that ride on a cushion of air. The two companies are pooling experience, technology, and seasoned personnel in a proposed project to build an amphibian machine for the Office of Naval Research.

Birth of the flying automobile industry is scheduled for this month as Temco Missiles & Aircraft Div., Ling-Temco Electronics Inc., Dallas, begins tooling for production of the Aerocar, versatile automobile-airplane developed by Aerocar International Corp., 1300 Nashville, Ft. Worth. The Aerocar is equipped with flight instruments as well as standard fluid drive transmission having three speeds ahead and one reverse. It has been Federal Aviation Agency type certified. (See article on aircars, page 52.)

space

A new space thermal installation at Space Technology Laboratories Inc., Los Angeles, duplicates the environment of space to within 10%. The rays from two Strong Electric Corp. carbon arc solar radiation simulators are beamed through a 10-in. port in the 12 by 7-foot vacuum chamber to reproduce the sun's radiation both in spectral distribution and intensity as it would appear outside the earth's atmosphere. Radiation bombardment is a major obstacle to survival in space. (See article on living in space, page 19.)

A prototype of an entirely new class of flight vehicles using wings of cloth or other flexible material was tested successfully by Ryan Aeronautical Co., Lindberg Field, San Diego 12. Ryan is studying adaptability of this concept for recovery of the first stage booster of the Saturn space vehicle for the NASA.

A new electronic generator with no moving parts, designed to convert the heat of a rocket exhaust directly to electric power to run steering controls of a rocket or guided missile has been developed by RCA's David Sarnoff Research Center, Princeton, N.J., and the Hunter-Bristol Div., Thiokol Chemical Corp., Bristol, Pa. Tests with both simulated and actual rocket heat sources have shown the feasibility of using thermionic tubes as efficient and lightweight power generators.

atomic energy

Use of existing high efficiency steam generating equipment coupled directly to an economical nuclear reactor is feasible with a new nuclear fuel. Fueled pressure spheres, developed by High Temperature Materials Inc., 31 Antwerp St., Boston 35, allow generation of uncontaminated 1200 F steam at 5000 psi without auxiliary heating or heat exchangers. Fission gases are contained within an impervious pyrolitic graphite coating applied over each fuel particle in the pressure spheres.

A technique for producing a useful source of neutrons in an energy range previously unobtainable with low-energy accelerators has been revealed by

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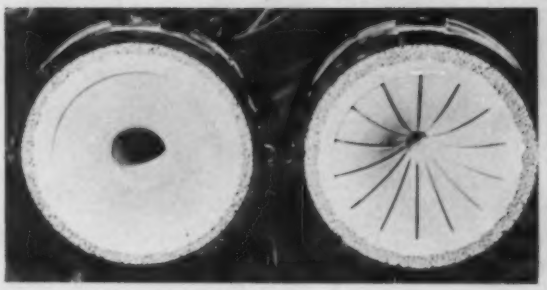

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nuclear physicists at Lockheed Missiles & Space Div., Sunnyvale, Calif. The technique involves bombarding a target of radioactive carbon (C^{14}) with heavy hydrogen particles known as deuterons.

metallurgy

Union Carbide Metals Co., 260 Madison Av., New York 16, has developed an oxygen refining process for chrome which is enabling producers of stainless and other alloy steels to make significant improvements in their melting.

A method of producing corrugated-core sandwich panels that reduces costs substantially has been developed in research sponsored by the Douglas Aircraft Co. at Battelle Memorial Institute, 505 King Av., Columbus 1, O. The method requires no jigging, provides completely sound core-to-cover bonds, and allows the panels to be extensively formed after assembly. The process, called roll-welding, uses hot rolling to pressure-weld the peaks of the corrugated metal core to the cover sheets.

Shaw Process Div., Avnet Electronics Corp., Port Washington, N.Y., has developed a new mold-making technique that permits mass production of high quality, high pressure metal castings at costs competitive with the crudest of foundry techniques. A composite mold consisting of a low cost sand backing with a special ceramic facing, both reclaimable, substitutes for the solid ceramic mold previously used for production of specialty precision castings and cast tooling. (See photograph No. **2**.)

electronics

A unique new fluorescent lamp adds a square form to point, linear, and circular light sources which have been available in the past. Developed by General Electric's research and engineering laboratories at Nela Park, Cleveland, the panel lamp is designed to fit a module 12 inches square, and offers a practical and convenient way of getting more light in a small space. It can be used singly or in groups, and lends itself to built-in, surface-mounted, suspended, and free-standing applications. (See photo No. **3**.)

Exploding light bulbs, one of the most common safety hazards, has been overcome in a new incandescent lamp through the use of silicone adhesives and glass yarns. Developed by Duro-Test Corp., North Bergen, N.J., the "Flamescent" lamp can be dropped onto a hard surface or dipped in ice water while in use without exploding into a shower of glass. (See photo No. 4.)

A scan converter storage tube can change the on-and-off pips of a radar screen to a complete television type picture of surrounding terrain as well as all aircraft and targets in range. Developed by the Electronic Tube Div., Allen B. DuMont Laboratories, 750 Bloomfield Av., Clifton, N.J., the new device is expected to find applications in airport and metropolitan area air safety radar systems. (See photo No. 5.)

A new class of active components, neither tube nor transistor, has been revealed by Philco Research Div.'s Basic Science and Technology Dept., Blue Bell, Pa. Called "metal interface amplifiers," the components consist of a thin-film sandwich of metal, metal oxide, and metal placed on a germanium substrate. The two metal layers and the semiconductor serve as emitter, base, and collector respectively. (See photo No. 6.)

Bell Telephone scientists have disclosed a method of producing synthetic speech in response to the typing of phonetic symbols on a keyboard. Before building the proposed "speaking machine" of the tandem resonant type, the scientists simulated it on a computer. The computer is programed to accept the names of the phonetic speech sounds making up an English sentence. This information is processed and the speech of the simulated machine comes out of the computer on digital magnetic tape. The tape then is converted to a variable magnetic sound track for playing on an ordinary tape recorder.

5

4

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chemistry

Butyl synthetic rubber with ozone resistance five times greater than that of conventional butyl rubber has been developed by the Chemical Research Dept., Esso Research & Engineering Co. The new rubber, MD 450, is expected to find application in advanced construction design, automotive weather stripping and seals, electrical insulation, extruded and molded sponge, and other molded goods, such as hose and tubing.

Elvax vinyl resin, a copolymer of ethylene and vinyl acetate, has been developed by the DuPont Co., Wilmington, Del., for use as a wax additive, wax extended polymer, and adhesive base. DuPont's Industrial and Biochemicals Dept. also announced the addition of Baymal colloidal alumina to the inventory of basic chemicals available to industry. In one form, Baymal is hard enough to machine steel or cut glass, while in another form it can be used to improve the smoothness of a skin lotion.

materials

Improved high temperature performance is offered by a new precision-moldable insulation material, Supramica 620 "BB" ceramoplastic, developed by Synthetic Mica Co., Div. of Mycalex Corp. of America, Clifton Blvd., Clifton, N.J. The new insulation will operate at temperatures up to 1200 F, and widens the range of problems ceramoplastics can solve in the vital area of missile and space research.

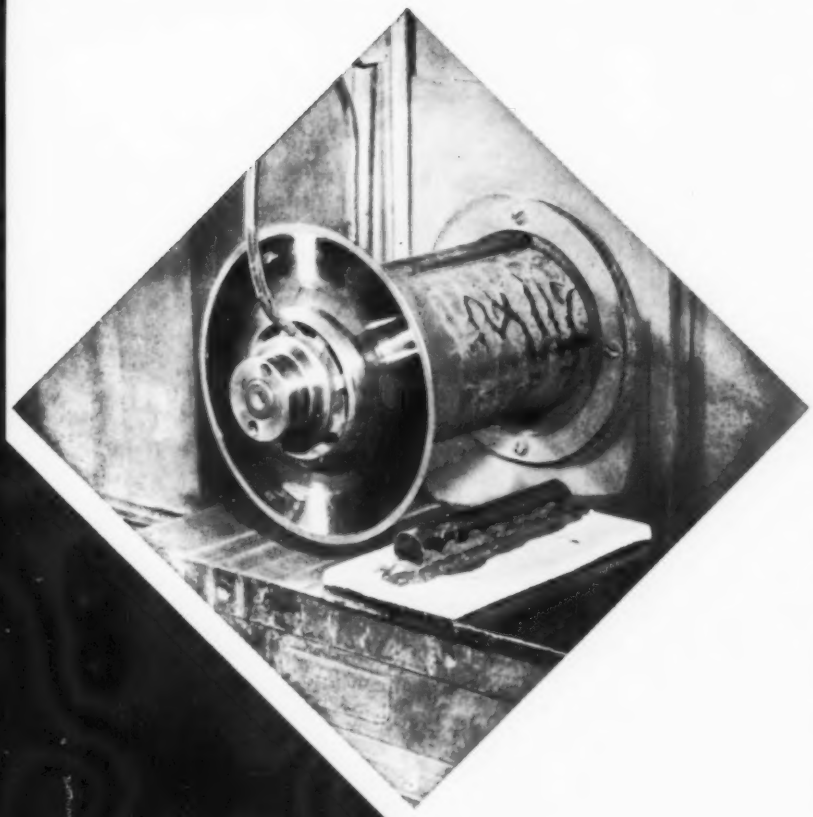
Exploratory work at the Ontario Research Foundation, 43 Queen's Park Crescent E., Toronto 5, indicates that fast-setting, very high strength concretes can be made from basic slags from the blast furnace. Such concrete would use pulverised slag as the cementing material and various sizes of slag as the fine and coarse aggregates. No sand or gravel would be needed.

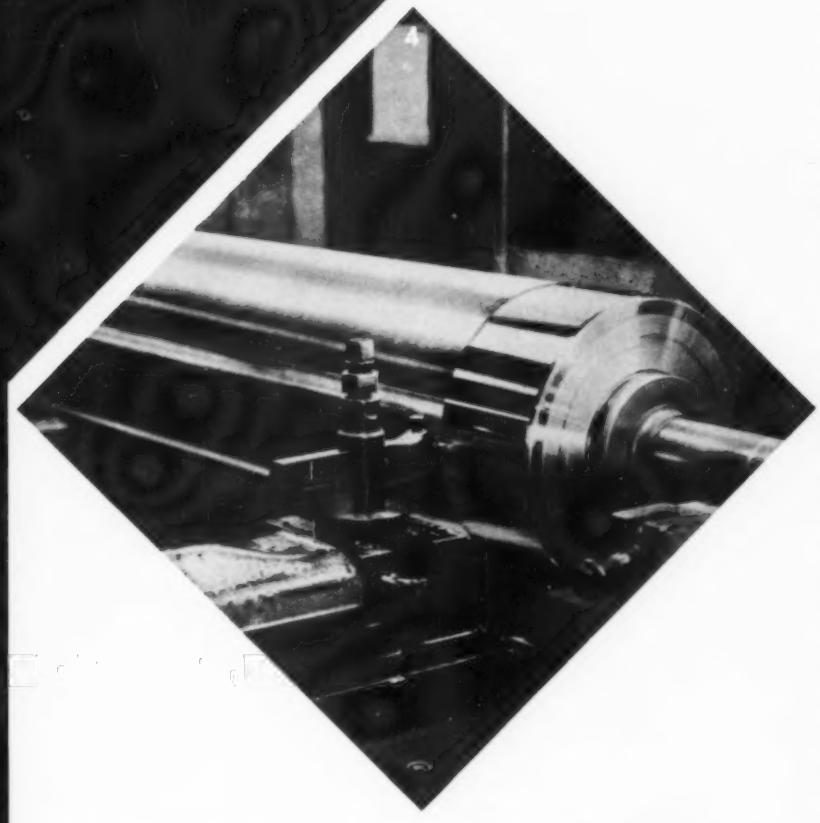
automation

Minute flaws in four-inch thick steel and other dense objects can be detected by a new gamma ray image intensifier system that projects images of the flaws on a TV screen. Used with the Picker X-Ray Corp. orthicon camera and Cyclops Cobalt 60 unit, the new intensifier tube is a development of Rauland Corp., subsidiary of Zenith Radio Corp., Chicago. The tube will permit an assembly line type of continuous inspection of dense materials--which previously could be inspected only by gamma ray photographs--and of other materials that could not be inspected without destroying them.

Development of the world's first automated catalyst analyzer is announced by Gulf Research & Development Co., subsidiary of Gulf Oil Corp., Pittsburgh. The new analyzer can be programed for automatic measuring and recording the micro-structure of refining catalysts. To test a catalyst, all air is evacuated from the sample and it is cooled to 319 F below zero. The analyzer repetitively doses the sample with nitrogen gas. When pressure reaches atmospheric, the device reverses the cycle by automatically removing controlled amounts of gas These changes in gas pressure provide the complete data.

Industrial Distributors (Sales), Ltd.





Look at the materials (and costs) that diamonds can cut

Everybody knows that industrial diamonds are used to grind and sharpen carbide tools. But did you know that diamonds can also cut and polish nonferrous metals like aluminum and bronze as well as glass, germanium, ceramics, marble?

Diamonds handle all of these jobs because only diamonds possess a unique *combination* of properties: excellent cutting ability coupled with fantastic endurance. Result: diamond tools last longer than anything else you can use. Your people spend more time producing, less time changing tools.

If you cut, sharpen, or smooth in your business, you can probably use diamonds to advantage. Test them against the method you're using. You'll find out how efficient—and economical—a diamond can be, especially now.

Best grit for metal-bond wheels

A new impact crushing method for natural diamonds (developed by the Diamond Research Laboratory in Johannesburg) is producing the strongest and most durable diamond grit ever obtained for metal-bond wheels. Your tool and wheel manufacturer is ready to help you select the diamond tool that's right for *your* job.

1 **Bimetal Bushings** *made at Federal-Mogul-Bower Bearings, Inc., Detroit, have steel shells with inserts of sintered bronze, tin, lead or aluminum. Diamond boring machine produces 15,000 in one shift. Inside diameters are finish-machined to tolerances of ±0.0005 inch.*

2 **Hardened Steel** *is ground with diamond-coated quills for precision grinding of small internal diameters at National Diamond Laboratory, Peekskill, N. Y. Miniature diamond wheels have greater strength and durability than small grinding tools containing conventional abrasives.*

3 **Germanium and Silicon** *are sliced with diamond wheel at Standard Rectifier Corp., Santa Ana, Calif. Cutters are powdered-metal matrix impregnated with small, blocky natural diamonds. No wear has been visible after months of use.*

4 **Copper-Plated Rollers** *of cast iron, steel or aluminum for gravure printing are smooth-finished in a single pass with diamond lathe tool at Southern Gravure Service, Louisville, Ky. Surface finish of about 6 microinches results. No coolant is required.*

Industrial diamonds cut practically everything... especially your production costs

LOW-COST EMPLOYMENT ADVERTISING

RATES *for classified advertising: 50 cents per word. Minimum 50 words. Count box number as six words. The form below is for your convenience, but need not be used. Checks must accompany classified orders.*

DEADLINE: *Classified ads must be received prior to Sept. 1 for the next issue, which will be published in late September.*

☐ Situation-wanted

☐ Position-open

☐ Other: _____

TITLE OF AD: _____

DESCRIPTION: _____

☐ I enclose check for $_____.
(Make checks payable to Industrial Research, Beverly Shores, Ind.)

Send inquiries to:

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company (if position-open ad)

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city *zone* *state*

employment clearinghouse

Now that INDUSTRIAL RESEARCH will be monthly (with the next, October, issue), it will be in a position to fill an important void in the services available to you—an employment opportunity section that directly recognizes your unique role as a member of technical management.

The section, to be called Technical Management Clearinghouse, recognizes that technical managers both hire high-level technical men, and on occasion are themselves interested in changing positions. Messages for positions-open will be placed adjacent to position-wanted resumes. The column will expose technical management to technical management, thereby providing the only service of its kind. If you care to use this service, the Clearinghouse will contain your summary of qualifications as a technical manager, executive, or senior scientist. Or it will present your company's openings to top technical men. Positions as president of a technical company; vice-president or director of research, development, or engineering; chief engineer; senior scientist; and similar titles will be advertised in the Clearinghouse.

No other publication specializes in technical management employment problems. Ads for personnel or positions at this level conventionally are placed in newspapers or technical journals where space rates are high and the percentage of technical executive readers interested in your message are low.

Because INDUSTRIAL RESEARCH is read and used exclusively by technical management, who may be seeking your qualifications or available positions, you will receive an unusually high exposure to your message at nominal cost. The circulation of INDUSTRIAL RESEARCH soon will be over 54,000 representing virtually all technical management in the United States.

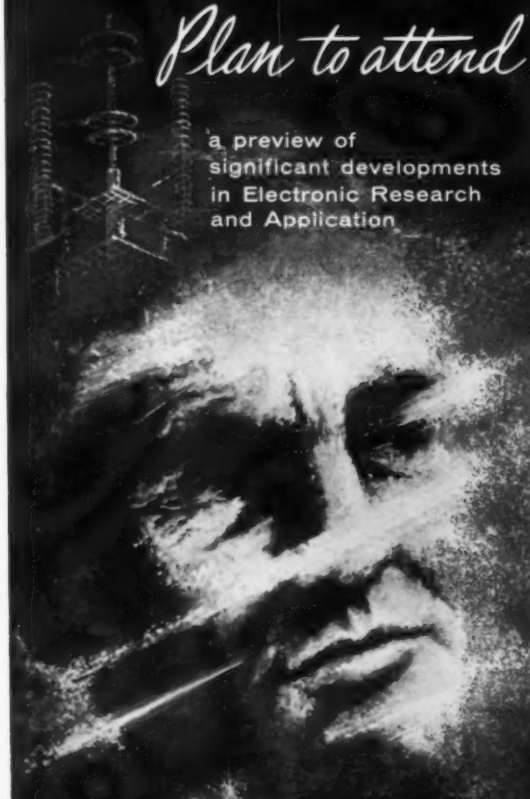
An important aspect of the Clearinghouse is the fact that INDUSTRIAL RESEARCH covers all technological fields. Thus, overlapping disciplines can be advertised correctly: chemical directors will reach the chemical, aerospace, metallurgical, and related fields; electronics instrumentation men will reach the metallurgical field, etc.

Classified rates are 50 cents per word, minimum 50 words. Count box numbers as six words. Closing date for both situation-wanted and position-open classified ads to appear in the next issue is Sept. 1. Checks must accompany insertions.

(Display ads also may be positioned in this section at regular display rates. For a rate card, write Advertising Dept., Industrial Research, Beverly Shores, Ind., or call any of our sales offices listed on page 72). ■

Plan to attend 1961 NEC

a preview of significant developments in Electronic Research and Application



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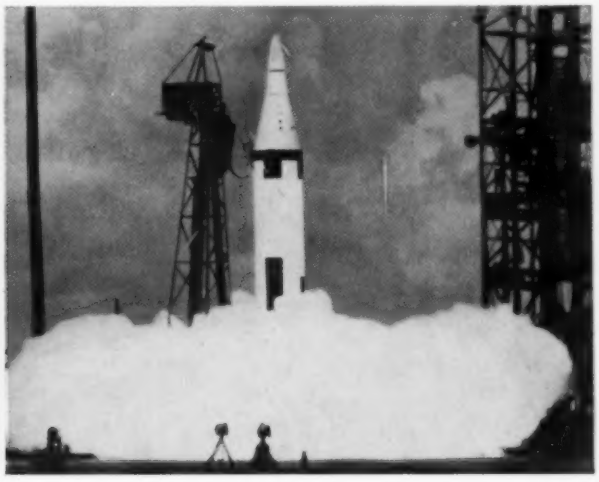

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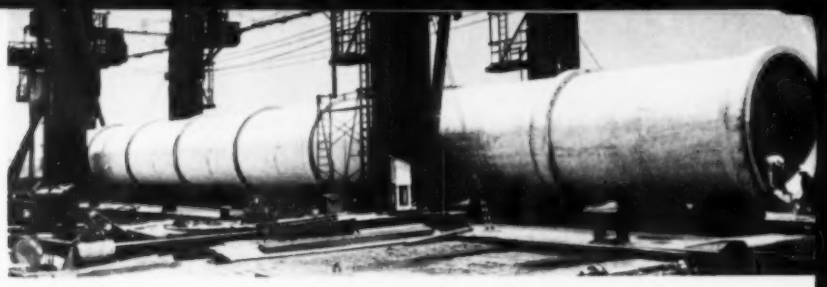


by **Neil P. Ruzic,** *editor & publisher*

THE ENGLISH CHANNEL TUNNEL: 159 Years of Research

AFTER 159 YEARS of engineering dreaming, political bickering, false construction starts, and about 4-million research dollars, the famous English Channel Tunnel will be built. Construction probably will begin in two years, immediately following the long-awaited British government sanction. Once given, a piggyback-railroad twin tunnel will take four to six years to build.

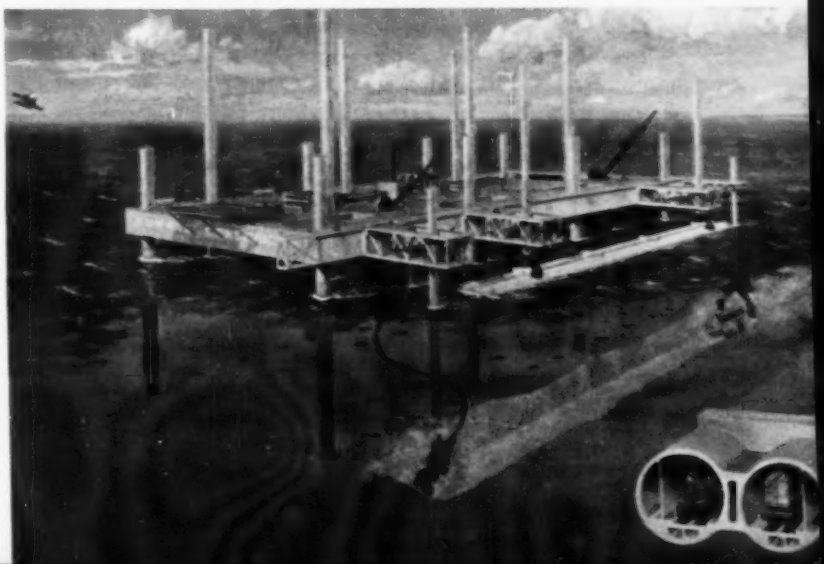
Many grandiose dreams of almost paranoid dreamers—men with ideas for electric lighting, the Panama Canal, airplanes, spaceships—have had to wait for the science of their times to advance. The English Channel Tunnel had to wait for that and for a few other things: complete trust between England and France, low ebb of British insularity, imaginative politicians on both sides, an economic situation where it would cost too much *not* to do it, ready world-wide financing, and last (and also least, as far as presenting an obstacle is concerned), feasibility of engineering.

Now, for the first time in history, all of these conditions exist simultaneously, making a completion estimate of six to eight years from today more than a mere guess.

The technology wasn't ready

The idea of connecting the two headlands with a tunnel came about in 1802 before it was technically possible to do the job. Engineer Albert Mathieu-Favier proposed creation of a small island near the channel center where a ridge, called the Varne Bank, rises to within 15 feet of the surface at low tide.

Mathieu brought the plan to the first consul of the French Republic, who talked it over with the British. A Franco-British peace treaty had just been signed and the British were interested in the tunnel. Mathieu envisioned horse-drawn railcars galloping under the channel from both England and France, meeting at the artificial island for a breath of fresh



IMMERSED TUBE *proponents propose laying a cut-and-cover tunnel under the English Channel, using a technique developed by Hyperion Constructors in laying 5½ miles of 12-ft. concrete sewer pipe (above) beneath Los Angeles Harbor. A "walking barge" (right), that can traverse the entire channel in rough water without its platform getting wet, would dredge the channel bottom for an immersed tube. Tunnel sections in lengths of 400 feet would be towed to the site, lowered into the pre-dredged trench, and then backfilled, all in a single operation. Five to 10 feet of fill would cover a single oval (or twin tubes as shown here).*

air. Later, the island would become a vast international city. And why not? The first consul, Mathieu's backer, was Napoleon Bonaparte.

Two years after that first tunnel discussion with the British, Napoleon looked across the channel at "the enemy" and the channel tunnel project died its first of many deaths.

Through the years the project was resurrected often:

- In 1803, Thessier de Mottray proposed to lay a steel tube across the seabed instead of boring beneath.
- In 1833, Thomé de Gamond, doctor, lawyer, chief engineer who was to spend his life on English Channel projects, planned to cross the channel with a steel tube extended section by section along the bottom inside a wall of masonry.
- In 1836, de Gamond offered a bridge across the channel in several styles and colors: black wrought-iron with a flat top, rust-colored steel with a tubular top, or granite piles with arches of syenite.
- In 1852, de Gamond swung over to a viaduct bridging the channel with 400 tubular steel spans carried on granite arches. He proposed the idea after a series of naked, weighted plunges *from rowboats* into water almost 100 feet deep to examine the geology of the area. He was the first channel tunnel engineer to emphasize the importance of underwater geology.
- Also in 1852 came Dr. Prosper Payerne's idea to build walls and roof under water with prefabricated blocks. All work, in up to 180 feet of water, would be done from inside a big diving bell.
- In 1855, the Abbé Angelini schemed to submerge a prefabricated iron tube by dropping it in the sea and hoping it would land "below the upper colite layer on the French side but above the white chalk on the English," a remark that showed a surprising knowledge of the geology.
- In 1860, the Frenchman Hector Horeau called for another submerged tube complete with Gothic pavilions and turrets to mark the existence of air shafts rising from the tunnel below.
- In 1870, Verard de Sainte Anne proposed a viaduct which used the Varne Bank as the central support for gigantic, cantilevered arms.
- In 1882, a similar plan was suggested by the Channel Bridge & Railway Co. Ltd. Some 72 stone pedestals would carry 73 spans of about 1,500 feet each. The bridge would rise 194 feet above high tide level.
- In 1867, it was a bridge made of iron wire strung 22 miles from coast to coast and supported on 30 pyramids of iron scaffolding.
- In 1869, a tube 25 feet wide made of ¾-in. cast-iron plate as reinforcement for 18 inches of concrete, was to float by its own buoyancy halfway between the surface and sea floor, to which it would be anchored by hawsers.

The tunnel is begun

In 1880, actual work was begun with the sinking of two preliminary tunnels at the foot of Shakespeare Cliff in England (6,500 feet) and at Sangatte in France (4,800 feet). The tunnel (actually the beginnings of shafts to a pilot tunnel) had begun; it became a mark of social distinction to be invited to *Le Tunnel*. Lord Wolseley, English chief-of-staff, was invited, and ended up killing the project with an insidious little "blue book" that portrayed French troops disguised as tourists pouring out of the tunnel mouth onto the island.

The tunnel project was revived in 1920, killed by the British cabinet; revived in 1930, killed by a seven-vote margin in the House of Commons (despite Churchill's and Bevan's votes to the contrary); and revived again just a few years ago.

The current revival began contemporaneously by groups in the U.S. and France. In October 1956, lawyer Frank Davidson commented to his friend, lawyer Cyril Means, Jr., that he and his wife had a difficult crossing of the channel on their recent trip to Europe, and they "wouldn't do it again until a tunnel was built under the channel." What began as a casual remark developed into a long conversation and a decision to look into the matter.

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Davidson and Means each sank $45 in the project and used it to hire a library research job. Davidson wrote two one-sentence letters to the old tunnel companies in England and France: the Channel Tunnel Co. Ltd., the largest stockholder of which is the British Transport Commission, operator of the nationalized railroads, and the Société Concessionnaire du Chemin de Fer Sous-Marin Entre la France et l'Angleterre, the company that still retains a legally valid concession from the French government.

The two lawyers then formed Technical Studies Inc., with offices in New York. Davidson became president, his brother-in-law Arnaud de Vitry d'Avaucourt, chairman, and Means, executive vice-president.

One-sentence reply

From the English came a highly British one-sentence answer, "*We thank you for your letter dated 14th December and in reply would inform you that this Company is not, at present, able to avail itself of the possibilities to which you refer.*" The French letter, for lack of a better address, was

sent by mistake to the Société Concessionnaire in care of the Suez Canal Co. (recently renamed Suez Financial Co.), thereby landing it in the hands of Suez director-general Jacques Georges-Picot.

Georges-Picot, in the midst of being put out of business in Egypt by Nasser, was eyeing the channel project as a way to keep the Suez Canal Co. busy, and alive. He called a meeting of the four companies in July 1957, out of which the Channel Tunnel Study Group was born.

Each company will have a 25% interest in the International Channel Tunnel Co., which will be incorporated after the French and English governments sign a tunnel treaty. Approval of the French government has been standing since the French tunnel company was incorporated in 1875. English approval depends upon everything from upperclass claustrophobia to the hard-dying "an-island-means-independence" feeling of the British commoner. If England joins the Common Market, English government action is certain to be swift; if not, the tunnel still has its best chance in history to go through.

Actually, the first step in the series of necessary approvals already has been taken. The Council of Europe voted on Aug. 22, 1960 to make an official recommendation to the British and French governments that they establish an Anglo-Continental land link. The second step will be approval by both cabinets; third step, a treaty; fourth, approval by the two parliaments; fifth, incorporation of the international company; sixth, sale of securities to the public.

From the date of step six, estimated at two years from now, the tunnel will be a reality in as soon as three years, seven months if an immersed tube, or as long as five years if a bored tunnel.

Two choices, both railroads

Of the literally scores of schemes that have cropped up in the 159 years since Napoleon kicked it around, tunnel plans now are narrowed down to two types, and both are railroad tunnels. Reason: ventilation. A highway tunnel, the apparent solution for linking the highways of England with continental Europe, would necessitate removing deadly automobile exhaust gases at a cost of at least 50% more for the total tunnel.

Electric trains not only do not exude exhaust, but the "piston effect" of their race down the horizontal cylinder would pull all the fresh air necessary. Also, automobiles riding piggyback on flatcars can move much faster: a constant train speed of 60 mph can be maintained without any trouble, as opposed to average auto speeds of 35 mph for the 35-mile tunnel. And trains are less likely than individual autos to get flat tires, be driven drunkenly, or otherwise disintegrate.

Nonetheless, the auto tunnel idea died hard in France. Even now, France is the battleground between the highway-favorers, called *routiers*, and the railway-favorers, called *cheminots*. The *cheminots* have it, not merely because logic and economy are on their side, but also because the Société Nationale des Chemins de Fer, which controls the nationalized French railroads, owns part of the Société Concessionnaire, which in turn represents a fourth part of the tunnel company-to-be.

This arrangement also is handy in putting the ferry boats out of business without a fight. Since the British Transport Commission and the SNCF also control the ferries, they plan simply and realistically to retire the boats, or most of them, lose money with the left hand, and make 10 times the amount with the right. To show their tunnel zeal, the BTC and SNCF have not laid a single ferry keel in the past four years, the normal rate being one per year.

Why not a bridge?

Owners of the few ferries that will remain, plus owners of the big ships that ply the channel through night, fog, high waves, and war, strenuously object to an alternative solution for connecting the headlands: a bridge. The bridge solution has had many advocates because at one stroke it would eliminate ventilation problems, provide almost unlimited capacity for both road and rail traffic, allow the use of diesel or other non-electrified trains, and serve as a world monument (you can't *see* a tunnel) to Anglo-French scientific sophistication.

The shipping interests caution that, in addition to establishing a navigational hazard, painting a bridge would mean lifetime work and lifetime salaries for hundreds of men. They apply this rule of thumb to the economies of bridges and tunnels:

- A mobile traffic system (ferry service, airline, etc.) splits its expenditures roughly into 80% inflationary costs, such as salaries and maintenance, and 20% frozen, or noninflationary, costs. A fixed system (bridge or tunnel) reverses the proportion. A tunnel is split into 20% inflationary costs as against 80% frozen. A bridge runs around 30-70, favoring non-inflation, but not quite to the same extent as a tunnel.

The rail tunnel, then, has won the race, and the only choice now is between:

1. A twin-rail tunnel *bored* 100 feet under the sea floor in the lower chalk, estimated at a cost of $307-million and five years.

2. A twin-rail *immersed tube* precast of concrete and sunk, 400-ft. section by 400-ft. section, in a trench on the ocean floor. Cost: $316-million and three years, seven months.

Cost is a toss-up. For a mere $9-million more you can have a submerged tube a year and a half ahead of a bored tunnel. The extra year's interest on the as-yet nonproductive principle, together with lost revenues, would more than eat that up.

After 159 years of study, finally will become a near resolution of

Argument 1: for a bored tunnel

Bored tunnelists (punless after 159 years of pain) claim they have the experience necessary, calling attention to successful bored tunnels everywhere and to the relatively new and unpredictable science of waterproofing and submerging a big pipe. Bechtel Corp., Brown & Root Inc., and Morrison-Knudsen Co. Inc., in writing a joint proposal for the work, point to their highly efficient "moles" used to bore tunnels through the earth's mountains, and to the indisputable fact that 100 feet under the channel lies the best tunneling material on earth: gray chalk, structurally strong, easy to excavate without blasting, essentially impervious to both seawater from above and artesian freshwater from below. Even better, two strata of poor tunnel-grade chalk—yet chalk and not water—lie above and protect the lower layer through which the tunnel would go. All that beautiful material just waiting to be moled away, like butter falling before a hot hatchet, cries for a natural (bored) tunnel. As if that isn't enough, add the negative factors that the English Channel is notorious for 40-ft. waves and strong currents, that the tubists have only some 25 years experience as against bored tunnelists tracing lineage literally to cavemen, that the tube would have to be laid in swift, almost fathomless, certainly record diving-depth waters of 180 feet or more, that "unprecedented" construction problems are involved in dredging a trench and securing the tube to the bottom, that bad weather could delay the whole operation for years . . . and the sum of these additions surely indicates a bored tunnel as the sanest, safest, money-savingest solution.

Immersed tubists patiently pick the premise to pieces.

Argument 2: for an immersed tube

Countering negative for negative, they ask what would happen if you run out of gray chalk or encounter serious fissures after 10 or 20 miles of tunnel? The white chalk of the upper layers (of which the White Cliffs of Dover are an outcropping) would crack; water pressure at that depth would make the job either impossible or extremely expensive. The thicknesses of structurally sound beds are unknown and cannot be completely determined; the presence of fissures, in-filled valleys, or water inflows could stop tunnel construction completely or make the cost prohibitive. As for the time involved, tube sections three, four, five, etc. can be under

a tunnel under the English Channel, whether bored or immersed, reality within the next decade as England and France political differences. World-wide financing is no problem.

TUNNEL TOOLS *proposed by bored tunnelists include the mole, shown at upper left, that will bore through lower stratum of chalk 100 feet under the English Channel seabed at the rate of 110 feet in a 24-hour day. The mechanical boring machine is shown in use by Morrison-Knudsen Co. at Oahe Dam near Pierre, S.D. Neither storm, fog, waves, nor tidal currents will interfere with construction operations if the tunnel is bored. To provide additional headings, or working faces, and to clear out debris, two main tunnels and a pilot tunnel would be drilled simultaneously. Bored tunnel operations do not present any hazards to navigation, proponents claim.*

construction (in the harbor of Boulogne) while tubes one and two are being towed out to sea (by only one 3,000-hp tug).

As for experience, the tubists are loaded with experience, though date they not to cavemen. Represented in the tube camp are Raymond International Inc., DeLong Corp., Healy Tibbits Construction Co., Macco Corp., Peter Kiewit Sons' Co., and Tavares Construction Co. Inc. (which jointly call themselves the "Hyperion Constructors" because they all participated in building the "Hyperion effluent outfall," a 12-ft. wide, 5½-mile sewer pipe laid in Los Angeles Harbor in 1959). Other tubists, affiliated with the Hyperion group by a joint proposal, are Kaiser Engineers & Constructors Inc., the French Entreprises Campenon Bernard, and the British Richard Costain Ltd.

Historically, it was immersed tube schemes that were ridiculed and ridiculous, but only because the technology of the times failed to give substance to the creativity of the de Gamonds, Payernes, or Angelinis.

Experience in a sewer

The dramatic story of the Los Angeles Hyperion job proved it can be done. Watch. Pipelaying begins by floating a huge 4,500-ton Texas-tower-type work platform into position. The platform is jacked up on its 275-ft. legs safely above wave level. A string of eight 24-ft. pipes slung below a giant pontoon is snaked under the platform, lowered to the bottom, still lashed to the pontoon, then joined to pipes already placed. The pipe sections, precast on shore around tons of steel reinforcing, fit together tightly so, when hydraulically rammed under water, they fit without a drop leaking through. Heavy rubber caulking goes on as an added precaution; when finished, the tube is pumped dry. The entire operation is controlled by deepsea divers, underwater television, and electronic monitors.

In applying this experience to an English Channel tube, the problem facing the Hyperion Constructors was how to move the work platform without it touching water. Obviously the legs couldn't simply be jacked up, as in the pacific waters of the Los Angeles harbor, and floated up and down and across ferocious 40-ft. waves.

The 'walking' barge

The solution, if the immersed tube alternative is bought by the governments, will be to construct a double 550-ft. "walking" barge—double in that one unit fits over the other and cantilevers away from it, pushing its own set of 300-ft. legs down into the channel floor. When done, the rear legs elevate, the platform slides over itself again, and another 400-ft., 20,000-ton section of oval-shaped, 50-ft. diameter pipe is laid. Even this information probably is secret, and DeLong Corp., which engineered the idea, isn't saying any more.

However, it is clear, at least in the tubist mind, that Hyperion & Co. can walk in this way on 400-ft. stilts from France to England, a distance of 22 miles, even in raging seas 40, 50, or 60 feet high (although the maximum waves anticipated are merely 35 feet high).

Not only will the platform walk without touching water, but it will dredge, lay the tube sections, and backfill all in one synchronized operation. A long tube 15 feet in diameter, held at the top by hydraulic jacks swung off the side of the walking barge, will end at the bottom in a rotating cutter head and hydraulic pump. The device will excavate 2,000 cubic yards per hour, thereby digging one 400-ft. section in 24 hours (see illustration on page 41).

Excavated material will be squirted into position on top of the now-positioned tube section. Five or 10 feet of fill will cover the tube, the top of the fill being even with the ocean floor.

If the tunnel is an immersed tube, geological exploration for all practical purposes is finished. The 11 vertical holes (eight in the ocean, one on each coast, and one on the Dover breakwater) that were bored in the summer of 1959 already have provided sufficient information about the bottom for tube-laying to begin (although as a precautionary measure additional shallow-depth boreholes would be drilled).

A look at the bottom

If the tunnel is to be bored, however, about 80 more vertical holes must penetrate the several chalk layers to achieve exact calibrations of the various materials and their solidity. The job is exciting, and exhausting. Choppy water is the norm. Ordinarily in underwater holeboring, a hole is driven and forgotten, the core being taken to the laboratory for analysis.

Not so in the channel. All holes have to be filled with concrete before the survey vessel can move on to the next location — just in case the hole happens to hit where the tunnel will go.

Isn't there a less painful, more scientific method of analyzing the bottom than peppering it with expensive, 200-ft. deep boreholes?

Technical Studies Inc. chairman Arnaud de Vitry thought there must be. De Vitry, Versailles-born, MIT and Harvard educated, youngest man since Napoleon to address the French Institute (at 29 in 1957 on the channel tunnel), found the answer in two new U.S. companies that had done significant geophysical work for oil firms: Telephonics Corp., Long Island, N.Y., and Alpine Geophysical Associates Inc., Norwood, N.J. The methods they used were sonar and related underwater sonic techniques originally developed for offshore oil prospecting and to test the strength of the ocean floor for jetties.

Underwater noise as a tool

Sonar, or echo-sounding, works by emitting a single high-frequency sound under the surface of the water. The noise is transmitted as a series of pulses, or "pings," part of which penetrate through the ocean floor.

In this way, every geological interface under the ocean floor produces an echo. The echoes, picked up by an underwater receiver, are amplified, filtered, and transcribed onto a roll of sensitized paper.

A more advanced device, called the "continuous seismic profiler," or "sparker," is similar except that the underwater sound source is a 12,000-volt electric spark. While sonar "pings," sparker "bangs." What's more, the bang contains a wide range of low frequencies as opposed to sonar's high frequencies.

A super-sparker, called the "repeatable acoustic seismic source," or "Rass" also is used to study channel geology. A mixture of propane and oxygen contained in a small torpedo is towed in the water behind the survey ship, and exploded with a spark plug. Very low frequencies are produced by the device, allowing penetrations into the seabed of more than 1,500 feet.

Such techniques were used during 1958 and 1959 because the bored tunnelists wanted to know the exact position of the gray lower chalk, the stratum that is impermeable to water. Did the gray chalk run in an unbroken layer from one side of the channel to the other? How far was it folded and faulted? Were there gouged-out pockets filled with water-bearing chalk or sand that could cause a tunnel bored through it to collapse?

The sound surveys worked surprisingly well, each confirming the other's findings as well as the results of the borehole studies. But, unfortunately, sonar and sparker simply give the position of the interfaces. Other methods will have to be used to identify the kind of rock above and below each interface.

Apple-coring the earth

The borehole is the most reliable (and most expensive) of available methods. A hole simply is drilled with a kind of weighted apple-corer, and the core examined in the laboratory to find exactly what has been causing the recorded echoes.

In the English Channel, this is no small job. The drilling boat must be positioned accurately over the hole during the entire operation, often in swift current. Four or more anchors hold the boat, and the anchor cables are let out or hauled in as the tide goes in or out.

The coring equipment is similar to that used to drive wells on land, except that the first stage consists of sinking a length of larger diameter pipe to act as a guide for the main shaft. Vagaries of weather and current, the difficulty of working from a boat, and reaching 200 or 250 feet below your position to drill a hole combine to set the stage for an alternative method.

UNDERWATER SONIC TECHNIQUE *using a 12,000 volt electric spark aided bored tunnelists to determine the exact position of the gray lower chalk under the English Channel. The continuous seismic profiler, or "sparker," shown here, differs from sonar in that it "bangs" while sonar "pings." The bang contains a wide range of low frequencies that are used to penetrate the geological interfaces under the ocean floor and produce different echos.*

Here again, holeboring can be replaced in many cases with sonic means. One new method, known as seismic refraction, employs sound waves from an explosion, as with the "Rass" torpedo technique. But instead of having the transmitter and receiver close together, they are separated. Sound waves pass down through the water into the ocean floor and travel along through the rocks on their way to the distant receiver.

By measuring the time it takes the sound to travel from transmitter to receiver, and by using pre-tested muds, sands, chalks, and rocks as standards, the investigators can identify the different materials encountered. However, the method is not entirely accurate, and will be used in the channel job to confirm, rather than replace, the borehole findings; the cost of boreholes, normally significant, is dwarfed by the $300-million project.

Even if an immersed tube is laid, borehole money is well-spent. As with all engineering and scientific projects, when state-of-the-art advances, technology skips to a higher coilspring in its spiral climb, and the next fantastic job gets done faster, cheaper, or in a way previously impossible.

Lost time and unmade dollars

In considering cost of the project and all its preliminary stages, a fact constantly plaguing tunnel promoters is that the longer it takes to get started, the more money is being lost. It is both a question of pounds, francs, or dollars remaining unmade, and of an expanded ferry service actually costing more than a tunnel over a period of years. Freight and people can be moved faster and 25% cheaper through a tunnel than by ferry.

Several firms, including De Leuw, Cather & Co.,

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Now you can handle gas with no leakage to three atmospheres... thanks to Hamilton Gas-Tight Syringes. A special Teflon* Resin coating is used to cover stainless steel plungers for firm, smooth, spill-proof movement. Leak rate is less than 3 ul per hour under a vacuum of 20 mm of Hg with no leakage to three atmospheres.

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Chicago, have made revenue and traffic surveys of the tunnel. Of the 6-million passengers now crossing the channel, 55.5% travel by sea and 44.5% by air. De Leuw's Walter A. Barry Jr. estimates that 68% of tunnel capacity will come from discontinued sea routes and 25% from air trips of less than 250 miles.

The number of passengers is to jump from 3-million the first year it's open to about double 20 years hence. Estimated revenue, based on an average fare of about $4.50 per person, will go from $14-million the first year to about double in 20 years.

Freight transportation shows similar projections — from 1,230,000 tons in the first year to 1,707,000 tons 20 years later, bringing an estimated $7-million to $9.5-million per year over that period.

New vehicles for a new tunnel

Since the tunnel will be all-new, innovators with all-new forms of transportation are rushing their ideas to Channel Tunnel Study Group headquarters in New York, Paris, and London. Giant scooters, electric busses (to eliminate the exhaust objection to an automobile tunnel), aircars, and ground-effects machines of all types have been proposed *(see "Aircars and the Terresphere," this issue)*.

One of the most radical is one of the few being considered seriously: Ford's Levacar. Actually the Levacar is "new" only because production models have not yet been built. Dr. Andrew A. Kucher, vice-president for engineering and research at Ford, developed the concept and coined the word 33 years ago.

The Levacar should be thought of as a wheelless, frictionless, railroad train, rather than as a hovercraft or aircar. It rides on a thin strip of air a fraction of an inch above closely spaced twin rails. Tiny jets of air under high pressure blast downward to support the vehicle just above the roadbed and outward to guide it along the rails.

Speeds of 500 mph have been attained with laboratory models! But unlike aircars or some other aircraft, disaster is not a function of speed. When a Levacar component fails, the vehicle slides to an automatic stop on the track; its "fall" is a mere 32nd of an inch drop.

Several U.S. railroads have shown more than a passing interest in the Levacar, and a new, low-slung, aerodynamic, bullet-shaped Levacar is being designed to comply with the dimensions of existing tunnels. For the channel tunnel, few changes in design would have to be made. Problably a second set of tracks would be built between the regular tracks, positioned low enough so conventional trains could go over them. Levacar runs then would be scheduled between train runs.

The Levacar under design, the X-5, would weigh 76,000 lbs. (about the same as a four-engine plane) and measure 11 by 124 by 13 feet high. Two three-bladed propellers would power the car, one at each end. If used under the English Channel, the tunnel thus would have a second source of forced ventilation, in addition to the piston effect of speeding vehicles.

As with airliners, braking can be accomplished by reversing the thrust of the props. Then, when the speed falls below 100 mph, mechanical brakes would be applied. Levacars could stop in about five miles.

Your trip, tomorrow

The scene is London. The time: three years, seven months after say a year beyond "D" day (British decision day). You step into a gleaming 124-ft. Levacar "Bullet" along with 50 other passengers. The Bullet roars a little as prop craft do, then heads for the International Underseas Tunnel at Folkestone.

Somewhere in between it reaches cruising speed of 400 mph, dips into the immersed tube tunnel, emerges near Calais on the French coast, and glides to a stop in Paris, some 40 minutes after leaving London.

When this will happen, and exactly how, is a matter of decision. The finance, the engineering, the construction are a matter of course. Unlike most new technological projects, further English Channel research is *not* indicated. After 159 years, it's slightly overdone. ■

Known to rout hawks a hundred times his size, the hummingbird is a creature of courage. But when he takes this risk, it is with a distinct advantage. His powers of flight are matched by none.

We admire his style. And we share the philosophy. Knowing that our own capabilities are highly distinctive, we too believe that they are a thing to be used with boldness. Two years ago, Fairchild pioneered commercial production of diffused silicon Mesa transistors. They became the industry's most widely copied types. But we developed direct replacements — silicon PLANAR transistors (PLANAR diodes too were developed) — another step forward. Our newly introduced PLANAR EPITAXIAL devices and MICROLOGIC elements continue the progress.

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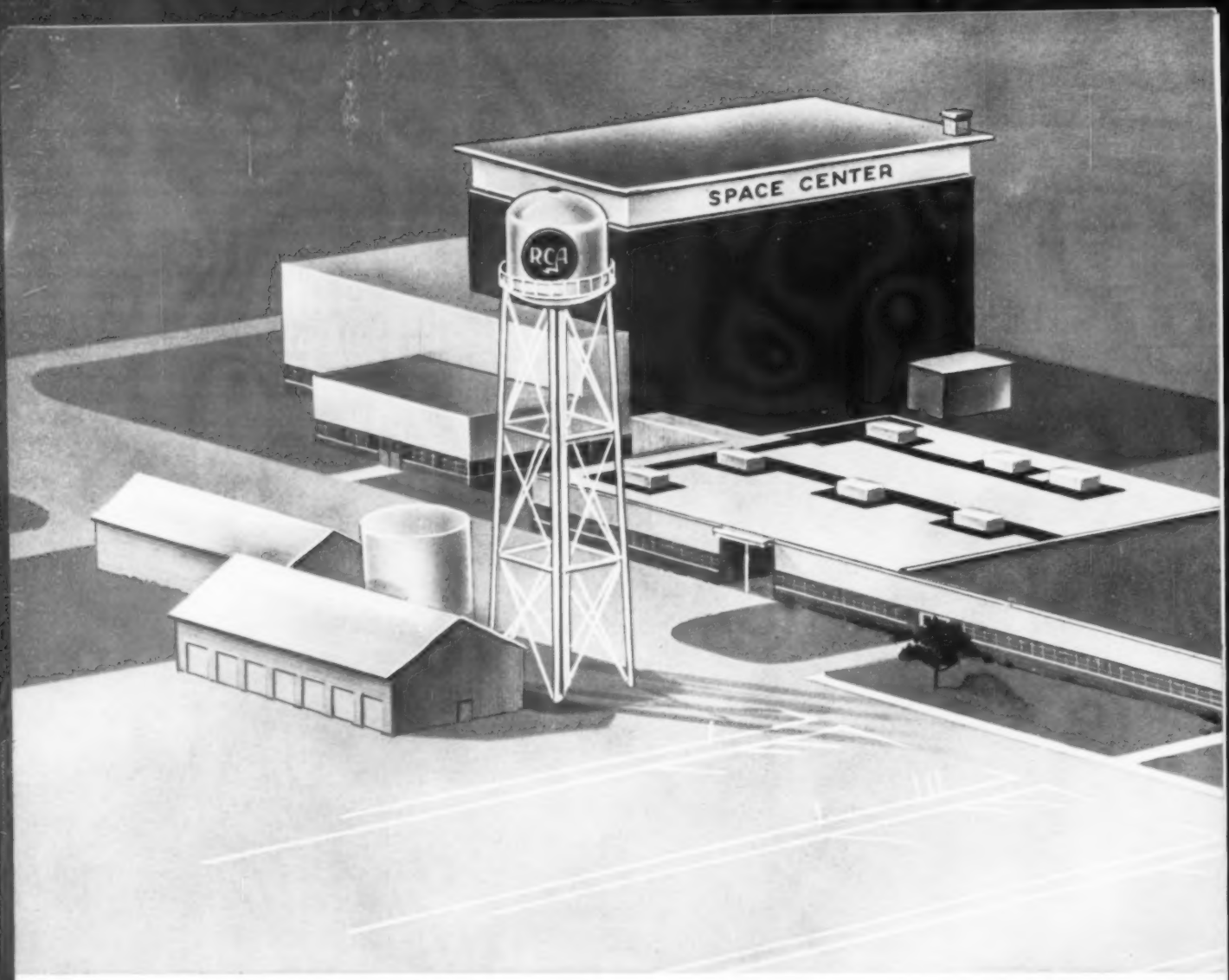


New RCA Space Environment Facility Brings Outer Space Down to Earth...

...Will pretest coming generations of U.S. space vehicles and satellites at environmental extremes assuring reliable long life operation and optimum performance.

RCA expands its proved capability to meet the challenges of space-age technology with the construction of an advanced space environment center at Princeton, N. J. Here, today's *and* tomorrow's space vehicles and satellites can undergo a new degree of intensive and thorough testing prior to "launch" to achieve greater reliability in space.

Included in the new environmental equipment and facilities being built and installed at the RCA Space Center are the following advanced testing devices:

Vacuum-Thermal Chamber—measuring 28 feet in diameter and 25 feet high to accommodate the coming generations of space vehicles and satellites and meet all vacuum-thermal requirements.

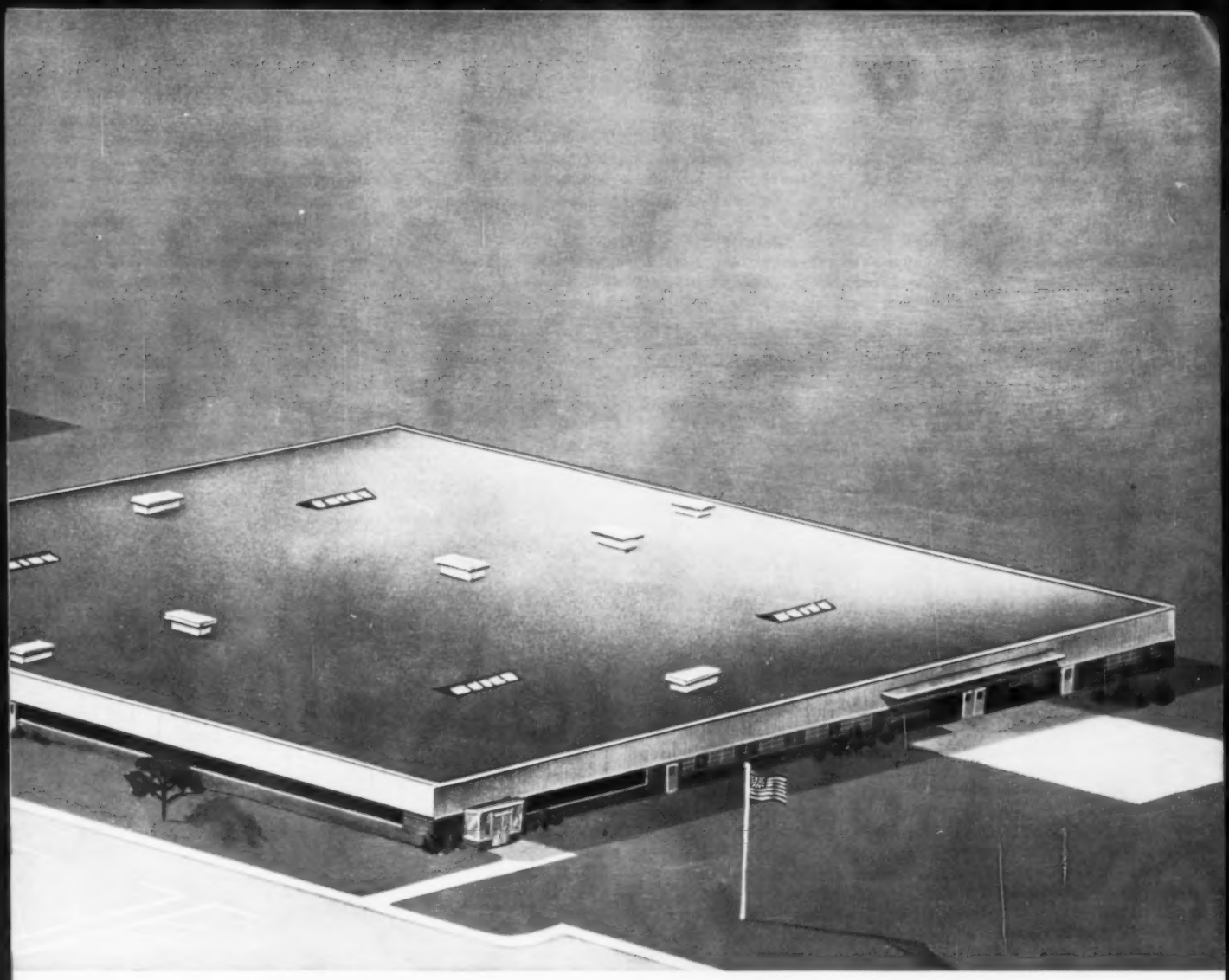
Vibration System—provides 28,000 pounds peak force for sinusoidal, and 28,000-pound rms force for random motion testing.

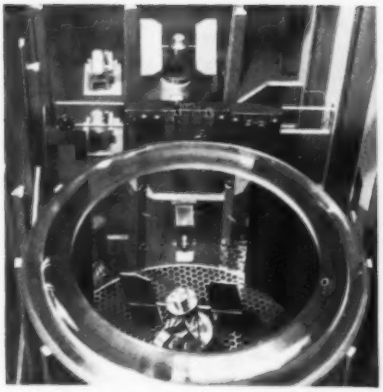
Temperature-Humidity Chamber—so versatile it can create virtually any thermal-humidity condition desired. Temperatures may be varied from —50° F to 250° F; humidity from nil to maximum.

Rotary Accelerator—subjects subsystems of space vehicles and satellites to forces as high as 2500 g lbs.

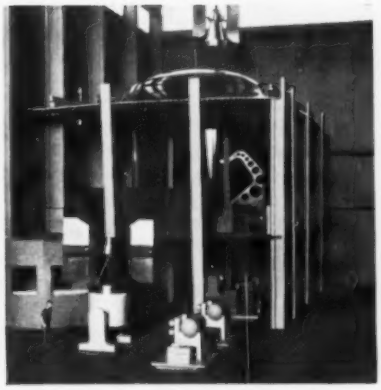
The entire RCA Space Center, which contributed to the success of projects such as SCORE, TIROS I, TIROS II and ECHO I, continues to be dedicated to the conception, development and production of earth satellites, space vehicles and ground support and information handling equipment. For additional information about RCA's engineering talents and proved capabilities, contact the Manager, Marketing, RCA Space Center, Box 800, Princeton, N. J. And, for a complete description of the new environmental facilities, write for your copy of the brochure "RCA Space Environment Center."

If you are interested in participating in the challenging opportunities that exist at the RCA Space Center, contact the Employment Manager, Astro-Electronics Division, Defense Electronic Products, Princeton, N. J. All qualified applicants are considered regardless of race, creed, color or national origin.

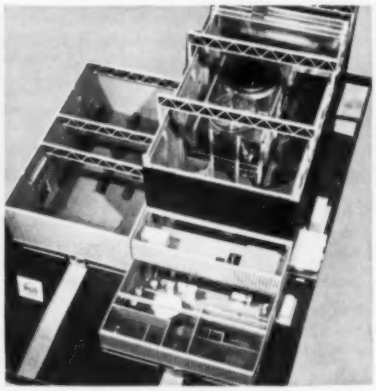




New advanced Vacuum-Thermal facility shown in model has pumping system that can reduce pressure to 5×10^{-6} mm Hg within 24 hours with a 3500-pound payload in the enclosure.



New Vibration System will include 28,000-pound exciter driven by an amplifier capable of delivering 140 KW over a frequency range of 25 to 10,000 cps.



All existing environmental equipment will be housed here and a new high-bay assembly area provides facilities for assembly of an increased number of space systems.

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A CLASS OF NEAR-GROUND CRAFT that ride on cushions of air or sprout wings or propellers is carving a new highway out of the very-low-altitude sky. This layer of newly important air, which we may call the "terresphere," ranges from an inch above the ground to a hundred feet over the treetops. It will become increasingly important as ground and conventional air vehicles enmesh themselves further in their own congestion.

Aircar prototypes, from backyard gadgets to complex vehicles, already have been produced. These experimental models generally can be divided into three types: the "aerial platform," the "ground-effect machine" (or "GEM"), and the hybrid "airplane-automobile."

Aerial platforms look like either flying ground vehicles, such as jeeps, or low-flying helicopters. All have some type of propeller, and accomplish free flight at altitudes just high enough to clear trees and low buildings.

Most ground-effect machines are round or elliptical disc-like objects, cousins of the fanciful flying saucers. They travel on an air cushion, ranging for various models, from a fraction of an inch up to two or three feet.

The third type accomplishes conventional free flight, then sheds detachable wings and tail for conventional travel. It does not realize the direct-line and amphibian features of the GEM.

Birth of a new transportation

Realists will be quick to throw cold water on so delightful a notion as aircars, but like airplanes and automobiles, aircars probably are destined to become an integral part of the American way of life—even, perhaps, our new status symbol.

What is the thinking behind aircars? How will they prove advantageous in the total transportation requirements of the country? What are the problems of development and, possibly even more important, what new requirements will such vehicles pose in the way of safety, operator skills, and regulatory procedures?

While there are numerous difficulties in designing, developing, and putting aircars into operation, it is apparent that the flying automobile, whether an aerial platform, a GEM, or a vehicle combining the features of both, offers some alluring advantages in certain types of transportation needs.

One advantage is comparative ease of movement over rough terrain. Helicopters have answered this need to an extent, but models developed so far are expensive to operate and make heavy demands on the person flying them. Aircars offer economy and simplicity of operation and will provide easy accessibility to regions now impassable by jeeps and other heavy-duty ground vehicles.

Several GEMs also have demonstrated their ability to operate over both land and water, combining a highly desirable versatility with the possibility of exploiting the shortest distance between two points—a straight line. For regions with severe winter weather, aircars have a natural advantage over automobiles by eliminating the hazards of driving on ice and snow.

The military is well aware of this aircar potential, and a significant part of experimental work and development to date has been done under defense contract. These vehicles would permit movements in enemy territory, over terrain and water in places where aircraft are highly vulnerable, and where travel by conventional land and water vehicles is dangerous or impossible.

Similar commercial transportation advantages also have been claimed for the "Levacar," still under development by Ford Motor Co. Several major railroads currently are investigating this high-speed land vehicle that rides on a thin strip of air a fraction of an inch above the rails. (*The English Channel Tunnel: 159 Years of Research*, page 41, this issue.)

The wheel-less, jet-cushioned Levacar operates on a slightly different principle from GEMs, which ride on a bubble of low-pressure air and can be lifted up to several feet above the ground.

Levacars may provide transportation between big cities 100 miles or so apart. Ford currently is designing a 200-passenger car to shuttle between New York and Philadelphia at 150 mph. The proposed test run on the 92-mile route—about a year away—is expected to take 38 minutes.

Backyard aircars

Aircars also have captured the imagination of amateur enthusiasts who have developed some interesting models. Using a chain-saw engine, an old tractor radiator, and some plywood, a 17-year-old boy in Alaska put together a flying machine weighing only 25 lbs. that operated three or four inches off the ground. Total cost: $4!

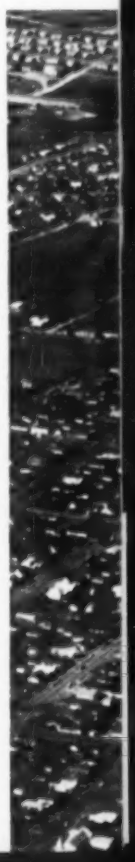
Two teenagers from North Carolina working through their high school science class also developed a low-flying craft. It operates an inch above the ground and can transport an 80-lb. payload.

While these precocious efforts may never lead to practical vehicles that can be integrated into our transportation system, they demonstrate that the principle can be put into operation economically.

At a considerably more advanced level is the work of Dr. William R. Bertelsen, Neoponset, Illinois physician. Bertelsen hopes to obtain an all-weather vehicle of significant practical usefulness—such as for rural medical practice.

His prototype, "Aeromobile 200-2," has been selected by the Department of Commerce Office of International Trade Fairs as "sufficiently well advanced in operation and control to merit demonstration in U.S. exhibitions overseas ' It was seen at the Fourth Tokyo International

Air



FLYING AUTOMOBILE, the "Aerocar," will enable private pilots to continue traveling even in bad weather merely by landing and folding the wings. Volume production is to begin this month at Temco Missiles & Aircraft Div. of Ling-Temco Electronics Inc. for Aerocar International Corp., 1300 Nashville, Ft. Worth, Tex. The airplane-auto is a four-wheeled, two-place craft in flight. A pusher prop behind the tail is powered by a 143-hp Lycoming engine. Convertible for road travel in 10 minutes, wings and tail can be folded and towed trailer fashion. Road speed is 60 mph, cruising speed 100 mph. It can land at 50 mph in 300 feet. Fly-away cost: $13,900.

Trade Fair from April 17 to May 6, is presently on exhibit at the "Italia '61" Centenary Celebration in Turin, and will be shown later this year at the International Trade Fair in Yugoslavia and at the Indian Industries Fair in New Delhi.

The model travels a foot above the ground, weighs a maximum of 2,400 lbs., achieves a forward speed of 60 mph, climbs long grades of 15% and short ones of 20%, and consumes seven gallons of 80-octane fuel an hour.

Some 15 American firms, such as Reynolds Metals Co., Dow Chemical Co., and Stewart-Warner Corp., contributed materials used by Bertelsen in his 200-2.

Racing toward a concept

Bertelsen and the adolescent inventors, in a different age, might have served the aircar concept as the Wright brothers served the airplane concept. But in 1961 they are faced with some formidable competition from experienced aircraft and engineering firms.

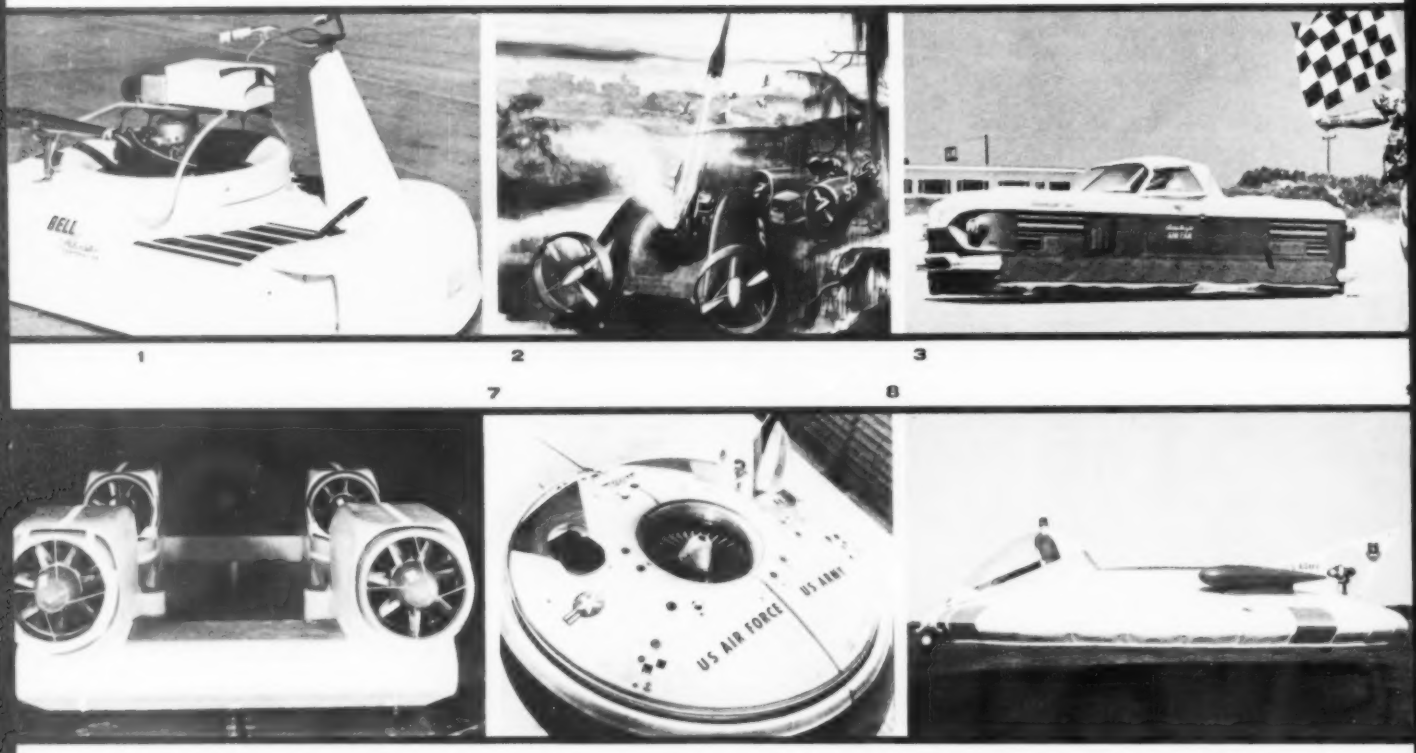
Grumman Aircraft Engineering Co., Bethpage, N. Y.; Hiller Aircraft Co., Palo Alto, Calif.; Chrysler Corp., Detroit, Mich,; Curtiss-Wright Corp., Wood-ridge, N. J.; Aerophysics Co., Washington, D. C.; Convair Division of General Dynamics, San Diego, Calif.; Vertol Division of Boeing Airplane Co., Morton, Pa.; Lockheed, Burbank, Calif.; Aeronutronics Division of Ford Motor Co., Newport Beach, Calif.; Erco Division of ACF Industries Inc., New York, N. Y.; and Bell Hellicopter Corp., Fort Worth, Tex., all in the United States, and the Valmet Corp., Finland, Folland Aircraft Ltd. and Vickers-Armstrongs Ltd., England, are testing GEMs and aerial platforms.

In addition, the National Aeronautics & Space Agency, the Navy's David Taylor Model Basin, Wash-

As president and founder of Applied Psychology Corp., Dr. Robert B. Sleight is concerned with human factors research. Formerly assistant professor and research psychologist at Johns Hopkins, he received his PhD in psychology from Purdue. Sleight is shown here as he prepares for take-off as driver of the National Research Associates aircar now being used as amusement ride at Disneyland.

by **Dr. Robert B. Sleight,** *president, Applied Psychology Corp.*

cars and the 'Terresphere'



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ington, D. C.; Iowa Institute of Hydraulic Research, and France's Office National d'Etudes et de Recherches Aeronautiques are engaged in aircar R&D.

'Aerocar' now in production

Volume production is expected to start this month on "AEROCAR," an automobile-airplane developed by AEROCAR International Corp. The developers have entered into a contract with Temco Missiles & Aircraft, a division of Ling-Temco Electronics Inc., Dallas, Tex., for manufacture of the vehicle, provided sufficient firm orders to justify quantity production can be obtained by July 1.

A four-wheeled, two-place, pusher-type vehicle when in flight, the AEROCAR is powered by a 143-hp Lycoming air-cooled aircraft engine both in flight and on the road. (See the Research Trendletter, this issue, page 29.) With the aid of a single hand crank, the craft can be converted from airplane to automobile in five to 10 minutes. Suggested basic list price for the Aerocar is $13,990 FAF (fly-away factory).

Since few aircars developed to date could be considered satisfactory for general operation and production, specific vehicles must be regarded as experimental. Among those in advanced stages of development, probably the most impressive is the Hovercraft (SR-N1), developed by Saunders-Roe Ltd. of England.

In 1959, it flew a 25-nautical mile trip across the English Channel at an average speed of 13.8 knots. This vehicle weighs approximately 9,000 lbs. and operates at an altitude of about 15 inches. It has demonstrated a potentially significant payload capacity by carrying 20 Royal Marines easily.

Scooting on air

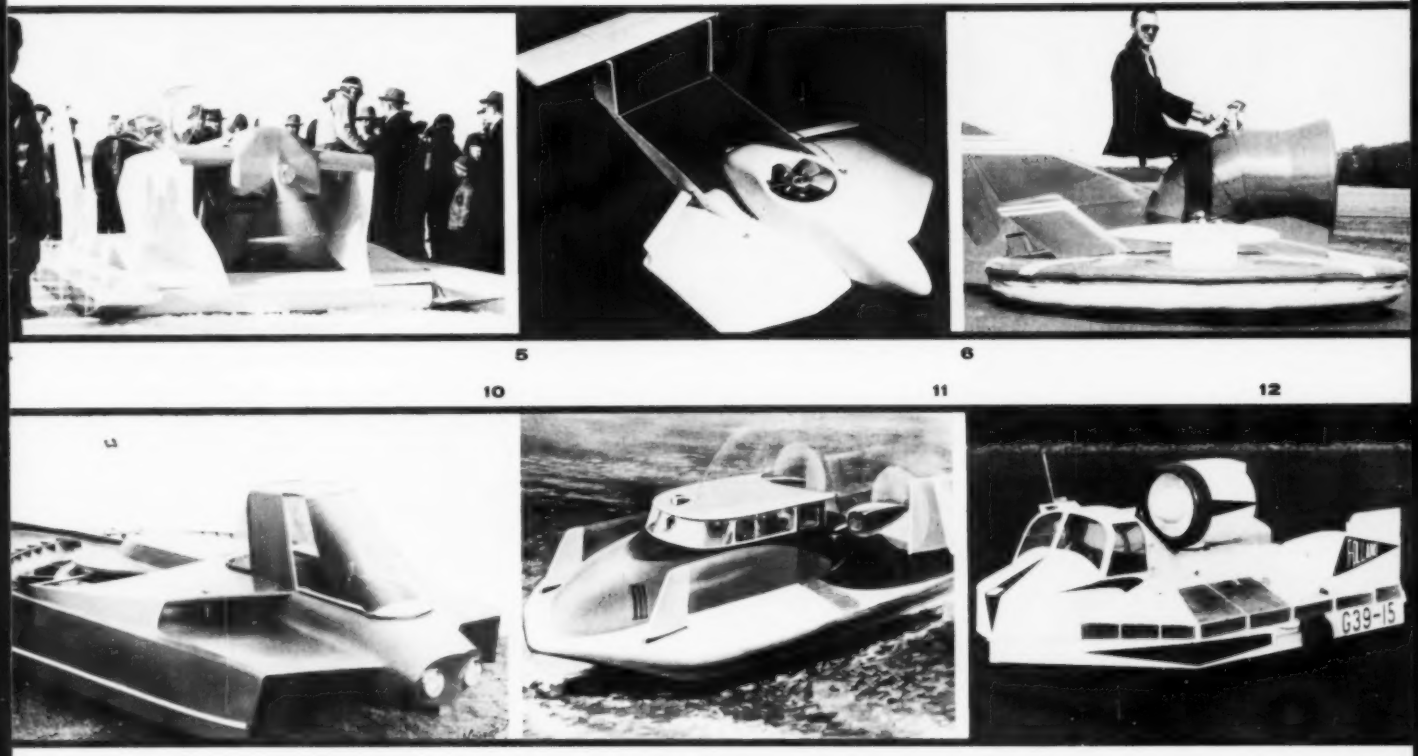
Princeton University's Dept. of Aeronautical Engineering has investigated several variations on the GEM idea, among them an eight-foot remote control machine, an air scooter directed by kinesthetic action of the driver, and a 20-foot diameter GEM which flys at 12 to 14 inches at speeds up to 25 mph. The vehicle is powered by a 43-hp engine and weighs 1,070 lbs.

In Switzerland, Carl Weiland has designed a craft to travel over water at high speeds, carrying a dozen passengers. Powered by two Oldsmobile engines, the machine operates on the "labyrinth seal" principle, a means of lift and propulsion somewhat like other air cushion designs. The main difference is that the air pressure beneath the vehicle is lowered in stages, so that a minimum loss of power occurs as the air escapes.

AVRO Aircraft Ltd., Canada, is conducting research under joint sponsorship of the U. S. Army and Air Force. The company's product, the "AVROCAR," is capable of operation, but the extent of its development is clouded in security regulations. The general aim of the work, however, seems to be to combine the ground-effect phenomenon with some sort of free flight capability, such as that of the aerial platforms or even regular airplanes or helicopters.

National Research Associates, Laurel, Md., has completed a prototype GEM for the U.S. Marine Corps. National claims its machine is the first such to be delivered to the government. It is an annular jet-type machine with a design speed of from 38 to 58 mph at a nine- to 15-inch altitude. Powered by two 40-hp Triumph piston engines, the vehicle is constructed of an aluminum alloy and is 14 feet, 7 inches long.

National also has offered its "Aqua-GEM," a 28-foot "tri-phibian" vehicle said to operate in water, over water, and over land. Its two 40-hp engines enable it to attain a maximum speed of 50 mph, and to cruise over weed beds, lily pads, sand bars, and mud flats. Gross weight is 2,400 lbs. with a 1,500-lb. payload. Its developers claim it's "ideal for marine operators, exploration



groups, fish and game commissions, mosquito control agencies, and sophisticated sportsmen."

Engineering the human factor

The popular history of invention too often seems to picture hoards of scoffers surrounding such persons as Fulton, Bell, and the Wright brothers. Yet, the temptation to caution the reader to learn from experience —and thus refrain from scoffing— hardly seems necessary. In view of constant breakthroughs in other areas, and with astronauts being conditioned for space flight, the idea of an aircar and the terrespheric byway is not especially startling.

The real temptation to be resisted is to postpone questions of procedures and facilities that would enable the new aircars to help solve our transportation problems.

The problem of development is largely one for the engineer, although in so radically different an area he particularly will need to work with human factors specialists. For if an aircar is to be accepted widely, it must be simple enough so that the average automobile driver can master it.

In addition, it will need to furnish a comfortable ride with seating space for an appropriate number of passengers; it must be readily "parkable;" and repairs and replacements of parts must be possible with reasonable ease. For commercial use, an aircar must be capable of carrying enough passengers or goods at reasonable cost and speed to be competitive with other means of transportation.

Roof top traffic jams

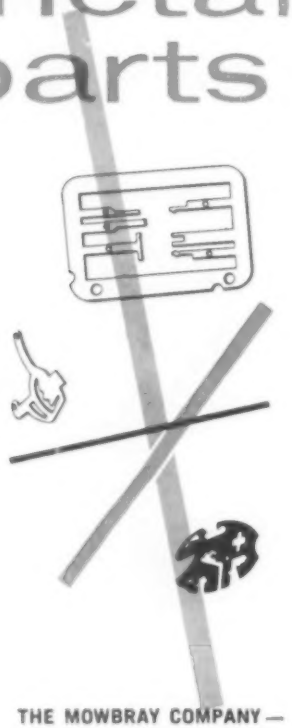
Safety will pose considerable problems in vehicle design and consumer acceptance. Some writers have portrayed air-motorists skimming over the tops of automobiles making their way from home to office at a brisk clip, free of traffic signals, traffic jams, and police. Yet, when the aircars are in widespread use, the evolution of their acceptance probably will be much the same as that of airplanes and automobiles. Where yesterday there was one, today there will be two, and tomorrow thousands.

Significant questions arise in contemplating such a situation. It is bad enough to collide with another vehicle on the ground. Colliding with another aircar a yard off the ground, at a speed of 60, 80, or 100 mph, is a good deal less attractive to contemplate. Rules of the road, realistic in terms of the volume of aircar traffic and prevailing speeds, must be worked out for terresphere traffic.

The vehicle itself will need to have some kind of built-in fall-breaker in the event of stalling, and it must float

AIRCAR PROTOTYPES *(above) under development by aircraft and engineering firms include: (1) Bell Helicopter's air scooter that travels over roads, water, ice, and snow at speeds up to 25 mph. (2) Ford Aeronutronic's proposed air cushion designed to carry 2½-ton payload five feet above the ground. (3) Curtiss-Wright's ACM-6-1, four-place vehicle, timed at 56 mph on land and 36 mph over water. (4) T. Kaario's design for Finland's Valmet Corp. that cruises at speeds of 50 mph with two aboard. (5) Ground effect take-off and landing vehicle proposed by Boeing's Vertol Div. for Army. (6) Second generation air scooter developed by Princeton University's Aeronautical Engineering Dept. (7) Electric powered wind-tunnel research model GEM 472 built by Navy's David Taylor Model Basin. (8) Disc-shaped AVROCAR research aircraft developed by Canada's AVRO Ltd. for U.S. Army and Air Force. (9) Army's P-GEM Model X-3B experimental flying car. (10) All-weather Aeromobile 200-2, developed by Illinois physician W. R. Bertelsen, that travels at 60 mph. (11) Hovercraft transport prototype by Vickers-Armstrongs Ltd. which will undergo over-water tests in England. (12) GEM research model, developed by Folland Aircraft, now being tested.*

thin metal parts



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in case trouble develops over water. Other considerations are sure to arise.

Regulation matters pose an intriguing question. Are aircars flying perhaps 30 inches off the ground to be considered aircraft, so that some kind of federal regulation or registration will be necessary? Or will they be regulated and policed by state and local jurisdiction? Legislation will be required to define the demarcation between land and air vehicles.

We can envision aerial traffic lights, air-squad cars, and airborne policemen, cloverleaf skyways, underpasses, and overpasses for ground and near-ground transportation. The problem appears ludicrous; yet a means of coping with it will need expert attention.

Very likely special rights-of-way will have to be developed for aircars, since neither pedestrians, drivers, nor property owners are likely to be amenable to the notion of thousands of aircraft flying at a height that barely clears people, automobiles, or buildings.

'Aircarways' through the 'terresphere'

Development of a system of "aircarways" would constitute one of the most important and wide-scale activities essential to the adoption of such a means of transportation. In the light of present knowledge, it appears to be a fairly reasonable project, costing substantially less than highways.

In many cases, the rights-of-way of present highways might provide adequate space on either side for aircarways to be set up. In other cases, broad rights-of-way similar to those now used for power lines would suffice. As long as all consequential obstacles are removed, no further preparation would be needed. Usually, a right-of-way could be prepared by a bulldozer with no surfacing required.

If the time comes that such a system actually is developed, then one of the greatest advantages of the aircar can be utilized—the straight-line course. An aircarway from Washington to New York, for example, undoubtedly would follow a much more direct course than automobile highways. Whenever suitable, over-water courses could be included as part of the routeway, eliminating the need of surface preparation and bridges.

Building buyer concept

Will the automobile driver who sees a stalled aircar—five or 10 years hence—shout his advice to the stranded driver to "get a car!" as automobile drivers were told to "get a horse!" two generations ago? What acceptance will an aircar have with consumers?

The degree of acceptance first will depend on the nature of the product. If the aircar offers as much comfort, speed, economy, safety, and operating ease as the automobile, plus superiority in some areas, we may expect considerable buyer acceptance. Development of favorable regulations and road facilities also will be important.

Both initial cost and operating and maintenance expenses will bear upon consumer acceptance. If the advantages are great enough, they will pay more than they would for an automobile—in proportion to the added advantages of the aircar.

The ideal aircar would fly very close to the ground as part of the regular flow of traffic over existing highways and waterways, as well as over special aircarways (land and water) which would permit more direct routing and higher speed. Because of its versatility, such a vehicle would have obvious advantages over those that can be used only under special conditions.

A time for planning

A principal concern should be with the planning and facilities required by a new transportation system. The history of other forms of transportation does not make an attractive picture. By this time we should have learned from these unfortunate experiences.

On the basis of prototypes already flown, the aircar certainly appears suitable to development as a means of private and public transportation. It also presents a number of important problems which will require expert and early attention, if we are to obviate the difficulties which prevail with every present form of transportation.

The aircar may be a big part of the answer to our transportation problems. Its very promise demands that adequate attention be given to the requirements it imposes on the individual, on business, and in government. Even though a really orderly development of a transportation system never before has been managed, it can be managed in the present situation by drawing from past experience, by doing the necessary planning at the right time.

There is little point in adding still another problem-frought form of transportation, when instead this new form can be brought into being properly with suitable planning at the right time. And the right time is now. ■

Toward a Theory of Design

COUPLING THE WORDS "theory" and "design" in the presence of engineers is sometimes dangerous. "It can't be done," they say. "You cannot make design objective." This article doesn't claim the opposite; rather it suggests that certain parts of the design activity can be handled with far greater effectiveness by using modern mathematical and computer techniques.

A typical response is "Why bother?" Such an argument goes on to note that engineering design is an ongoing function now peopled with experts trained in universities and companies. "Engineering design results speak for themselves. Anyway, it can't be done."

It must be painfully clear that our technological society has a tiger by the tail in its vast engineering resources and its incessant clamoring for more. Engineering design activities have grown exponentially in the last decade—an explosive increase in the number of people involved and an explosive growth in the need. Engineering design is in management's eye more than ever as it becomes a larger cost component in industrial operations. If it is to be controlled intelligently, if it is not going to run amok, then some rationality in the process of engineering design is a must.

Or, turning the matter around—the reduction in design response time and in design cost and the increased capacity of a design activity—all can be very large, indeed, by realizing objectivity in design to whatever degree is possible. There are many who can fill in the statistics on this matter. Just a little imagination should suffice at this point to show that "bothering," after all, is important.

What currently is possible and foreseeable in objective design constitutes a primitive theory on which much building has to be done. But this easing of the position still fails to quiet defensive voices. Explanations, examination of design activity, and understanding all are needed to enlist the vital aid of those active in the field. For if any theory of design is to emerge, the "artists" are fundamental; they must work with analysts in the development process.

This discussion will touch on a few aspects of design theory, such as it is at this point, and will review some specific experiences in objective design. It will be a once-over-lightly, but if it piques your interest by showing what can be done and points out enormous benefits that can accrue, then it will have achieved its purpose.

Artistry in design

Design can be defined as determining the appropriate materials and equipment to produce a given commodity or service. Basic science offers the properties of materials involved and, to some extent, the interacting properties. The design engineer must juggle these about in new combinations to meet new needs in machinery, equipment, electronic components, chemical plants, and so forth. Design is an integrating process involving the selection of these appropriate elements from a massive collection of possibilities.

The very massiveness of the total collection has given the process its artistic, creative flavor. For, given the *specification* of a function to be performed by a resulting mechanism or circuit or chemical, no two designers working independently are likely to produce an identical engineering design.

Somehow this fact is resented since it doesn't smack of science—but the very dedication to creativeness on the part of engineers can be cited as their own recognition of the paradox. Although scientific knowledge is used in design, it remains to a large part an artistic, brewmaster process and a rather personal thing to most people.

by **John M. Allderige,**
associate professor,
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Objectivity in design

Artistry by itself is not to be condemned. The point is that functional design can be made objective to some degree and therefore can be made substantially more productive and more effective—an ever-present goal for industry. We are close to being able to take the specification of, first, what is wanted in the way of performance for certain chemicals or mechanisms, and, second, the production restrictions — *and* generate objectively the collection of elements that will produce, or most closely approximate, that specified performance.

Modern mathematics and computers make possible a logical process of selection even with a massive list of possibilities. Mathematics can generalize design experience and computers can effect the large calculations implied by the mathematical structure. This is not a "unified field theory" of design—rather a selected area of experiences suggesting a major breakthrough in the process of design may not be far off.

Standardization vs. design 'bending'

At one end of the design spectrum, we can find a fairly common experience in objective design standardization. Whenever you want a particular nut and bolt, you could draw up a specific set of requirements: a design. However, it has been found that economies gained from common agreement on certain standard varieties more than offset costs of "bending" the design to meet available materials.

The low cost of "bending" a design does not always exist. But it occurs often enough to make standardization a workable thing. Electric motors, for instance, often are merchandized on the supposition that it is less expensive to offer a more effective unit than needed, even at higher manufacturing costs, than to design a unit for specific needs. In other words, designing costs money.

It might be well to dwell a moment on just what this means and what light it sheds on the design process. Given a standard set of units, each with a range of specifications, a non-engineer can perform the design function by tabulating this material. That is, he can go from the specifications to the mechanism (a motor, in this case) that can achieve the specifications in a single table-look-up step.

It can be argued, of course, that this really isn't design, that predesign has been done, and so forth. Nonetheless, a specific engineering response to a specific request no longer is necessary, and no matter what the label, this process is less expensive and releases more engineering time than designing anew each time specifications vary slightly.

The extent to which standardization can go is hard to say. At one extreme, one standard item of a type could be offered to serve all purposes. This would be applicable only when specifications are just one-sided: a motor of *at least* 10 horsepower, for instance.

Such an extreme is absurd in some cases — a standard 500-hp motor hardly would seem appropriate for a ¼-hp need. But it does present the problem of the number of standard levels or groups. The more levels, the more difficult and time-consuming it is to set up the system and the less manufacturing advantage gained. And for two-sided specifications, the cost of "bending" the design specifications goes up as the number of levels or groups get smaller. Design of a standardization program is still unresolved, but standardization itself is an example of objective engineering design.

Finding a formula in a cardstack

Consider a typical industrial coatings manufacturing plant. It has an active laboratory that formulates coatings based on specifications provided by a potential customer. In the course of its existence the laboratory has formulated close to 5,000 separate products. Whenever a new set of specifications is put to it, the question arises whether this particular formula has been done before, or whether some previous formula would satisfy the specifications listed.

Formulas are filed, to be sure, but it is not the easiest thing in the world to scan several thousand formula cards. It is almost easier to reformulate, and this is what usually is done.

If a previous formula had occurred within a very short time, it is quite likely that the memory of one of the people in the laboratory would be jogged sufficiently and that a more direct search could be undertaken with some success.

Company chemists experience the feeling that they have done a formulation at an earlier date, but are not always able to remember exactly when it was, nor have they the time to pursue their files methodically on the matter. The matter is really complicated because the specifications, aside from pigments, can have as many as 18 characteristics. It is extremely difficult on sight alone to tell in a general sense whether one formula is really similar to another formula.

The problem is not unique to the chemical industry; it prevails in any engineering design situation. The problem of formulas in glass and lenses is one example. Another exists in mechanical design where components often have been designed more than once in an engineering department, ostensibly to achieve the same end function. Another is component design in the electronics business.

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NIELS BOHR'S TWO-DIMENSIONAL *original conception of the atom, shown at the left, is not a representation of a "thing," but of a guiding idea. Just as Bohr's image is historically the first imaginative step toward more recent models of the atom, now embodied in equations and no longer a graphic representation, so the theory of design advanced by Alldredge in this article is merely a step toward objective design. Although physicists had catalogued the different wavelengths emitted by atoms of the elements nearly a century earlier, it was not until 1913 that a model was evolved to explain the phenomenon. That model was Bohr's radium atom which solved the puzzle when Bohr assumed that electrons orbit around the nucleus of the atom, causing emissions when they changed orbits. The diagram, showing orbits of the 88 electrons in the radium atom, serves here as a representation of objective design. Bohr's atom model is not an original drawing, but evolved from nature. If a major breakthrough in design is to be achieved, says Alldredge, engineers, too, must go back to nature. Mathematical, statistical, and computer attempts must be made to capture basic relationships of past experiences. Another course of action suggested is to speed up standardization and information retrieval programs as a step toward objective design. By feeding back specific design experiences and watching the process in action, progress can be made toward a theory of design. And just as Bohr achieved beauty as well as scientific significance in conceiving his radium atom, so engineers can obtain artistry as well objectivity in designing a commodity or service.*

Computerization

In another company, formulas were set down with a complete coding of all 18 characteristics plus price and identification codes. These were punched on computer cards to make up a formula library. Sorting equipment then was used to examine cataloged formulas against specifications that had been sent to the company. The diagram below shows how a punched card can be set up to hold appropriate information.

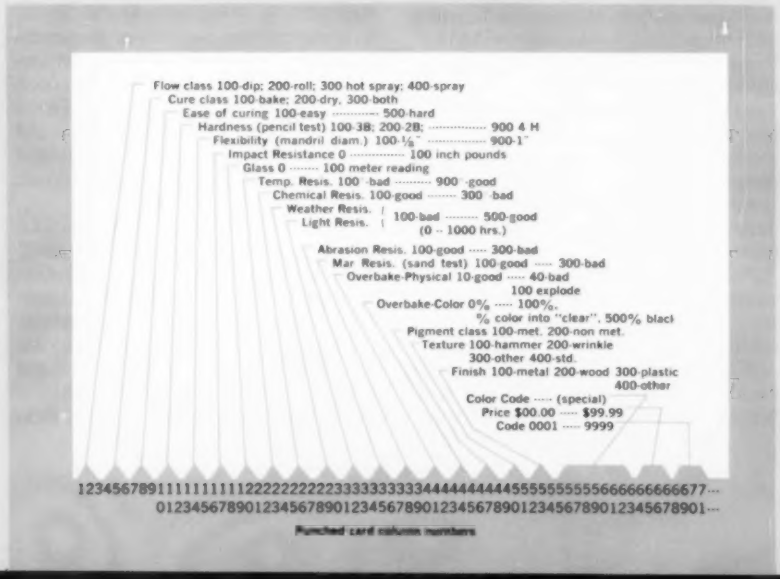
Information retrieval can be achieved in many ways *(see special section, April-May '61, Industrial Research)*. Punched cards, punched paper tape, magnetic storage drums, and other methods can be used. All have a memory system with a reasonably rapid and automatic access. Sorting is basically a simple procedure from the viewpoint of a computer. Once a code or form for characterizing the information can be achieved, implementation is relatively simple.

There is nothing new or particularly startling about the computer concept except the infrequency with which one encounters it in industry. Undeniable difficulties exist in characterizing a component or element in many engineering fields, but even if done only partly it would seem that considerable time could be saved.

Managements that practice any version of such a system have no doubt about its paying for itself. All that appears to be required in many situations is the energy to put this powerful idea to work. Computerization can offer some degree of objectivity in design and is another example of such a possibility.

Predicting from past characteristics

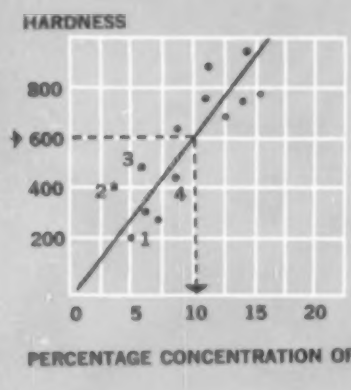
From the chemical engineering field and industrial coatings formulation comes an experience in objective formula design (formulation)


Flow class 100-dip; 200-roll; 300 hot spray; 400-spray
Cure class 100-bake; 200-dry, 300-both
Ease of curing 100-easy 500-hard
Hardness (pencil test) 100-3B; 200-2B; ..... 900 4 H
Flexibility (mandril diam.) 100-1/8" ..... 900-1"
Impact Resistance 0 ..... 100 inch pounds
Glass 0 ..... 100 meter reading
Temp. Resis. 100 -bad ..... 900 -good
Chemical Resis. 100-good ..... 300 -bad
Weather Resis. } 100-bad 500-good
Light Resis. } (0 -- 1000 hrs.)
Abrasion Resis. 100-good 300-bad
Mar Resis. (sand test) 100-good 300-bad
Overbake-Physical 10-good 40-bad
100 explode
Overbake-Color 0% 100%,
% color into "clear", 500% black
Pigment class 100-met. 200-non met.
Texture 100-hammer 200-wrinkle
300-other 400-std.
Finish 100-metal 200-wood 300-plastic
400-other
Color Code ..... (special)
Price $00.00 ..... $99.99
Code 0001 9999
1234567891111111111222222222233333333334444444444555555555566666666677...
0123456789012345678901234567890123456789012345678901234567890123456789...
Punched card column numbers

***A PUNCHED CARD** can be set up similar to the diagram at left to hold information necessary for a complete characterization of a component, and thus provide a degree of objectivity in design.*

using regression techniques. Many readers may recognize this procedure under the more familiar name of correlation analysis. As an example, it might be a technique for relating historical characteristics and then using this relationship for predicting results.

In one case, the concentration of a single chemical (call it *A*) might be related to the only characteristic that can be specified—say, hardness—in the following manner:



PLOT OF HISTORICAL DATA *is shown above. Numbers refer to specific formulas and the line is a "best-fit" obtainable with a straight line approximation. Thus, a hardness specification of 600 would suggest a 10 percent concentration of A.*

Given this relationship above, any future specification of hardness can produce the appropriate percentage concentration of *A* merely by looking at the graph.

The example is simple, but it does demonstrate an idea that has been expanded. The relationship is an input-output relationship and in any realistic instance, input elements and output characteristics are numerous.

In the coatings example above, 18 output characteristics and several hundred ostensible input variables—chemical elements or compounds—are available as basic ingredients. Extension of the simple example would call for relating each of the 18 output characteristics with the several hundred variables—a formidable task even with our most modern computers. The basic idea of the approach, however, still is demonstrated.

Reduce the complexity

Complexity can be reduced to make the problem solvable with current equipment. The output characteristics are not independent; they are related in most cases, for instance in coatings hardness and gloss.

In fact, all of the 18 characteristics have *some* degree of correlation, and these interrelationships can be captured by a mathematical technique known as factor analysis (or multivariate analysis of the method of characteristic vectors or principal components). This technique produces *indices* (factors or characteristic vectors) to describe the output characteristics and replace the conventional measures, such as hardness, gloss, and temperature resistance.

These factors are dimensionless and nameless, but unique. Given a set of 18 values, three index numbers that are almost equivalent to the 18, can be calculated from the original 18. Any change in one or more of the 18 yields different values in one or more of the three. These three index numbers, then, are a lot easier to deal with since there are only three, not 18.

Input variables also are subject to some kind of "space reduction." In the chemical example, the compiling of many elements and compounds occurs only in specific and somewhat limited combinations. Instead of several hundred independent variables, there were only 36 when all of these couplings had been accounted for.

Moreover, certain specifications have certain zero quantities—certain inputs never would affect the output specifications because these input quantities do not appear in the formula, which helps simplify the problem.

With the reduced output and input space, it is possible to carry out regression analysis of the index numbers on the real input variables. In the coatings example, this resulted in three analyses, each producing an equation of the following nature: $x = an_1 + bn_2 + cn_3 +$, etc. up to n_{36}, where a, b, c, etc. are coefficients with numerical values determined by the analysis, n's are the unknown amounts of the different inputs, and x is the calculated value of the index number. With three such equations, then, the process of formulation is derived thus:

- Given 18 specified characteristics, convert these to three index numbers.
- In each equation, assign zero values to those variables that obviously have nothing to do with the problem.
- Estimate values for the other variables, *leaving the three most important variables as unknowns.*
- Solve the three simultaneous equations, now with only three unknowns.

The process of formulation has been done in a preliminary fashion in coatings, with varying degrees of success. Some formulas so derived are similar to the purely intuitive formulas. Others are different and, frankly, not particularly good. The process is not completely satisfactory yet, but it has demonstrated sufficient success to support continuation of the effort.

As it stands, the process relies heavily on the major knowledge of the chemical engineer. Some of the subtler knowledge, which many times can be a severe stumbling block, is handled mathematically. In considering an extension of the process to other fields, it seems natural that similar reliance on the engineer's knowledge would be required. The same problems of putting measure on output, presented in information retrieval, still are present and the problems of establishing or defining an input are even more difficult.

Machine design with its wide range of size and motion characteristics demonstrates some of that difficulty, but chemical problems actually are more straightforward in these respects. It does offer an ever-enlarging experience in objective design, however, and work should be done in studying and extending this experience to other engineering fields.

Optimum designing

Mathematical programing might better be called optimum designing, since it deals with getting a "best" design within certain restrictions by using the mathematical programing technique. The following example, again, is a simple one extracted from operations research literature, but it does express an important idea involving the systems design problem confronting space vehicle engineers:

If the system consists of two components whose reliability can be improved by adding reserve units which could be cut in should the initial unit fail—and yet whose cost and weight cannot exceed certain limits—how many reserve units of each kind can be put into the system?

Suppose the reliability of component one is 0.9—that is, it has a 90% probability of functioning satisfactorily over the lifetime of the system. If there were two units of component one, with the second ready to be switched in upon the failure of the first (and, for the moment, with a perfect switching mechanism), then

the reliability of component one would be 0.99, arrived at as follows:

- Reliability equals 1.00 —probability of failure.
- For a single unit, 1.00 − 0.1 = 0.9 (That is, there is a 10% probability of failure.)
- For two units, the probability of failure = the probability of one failing × the probability of the other failing = (0.1) × (0.1) = (0.01).
- Hence, reliability for two units = 1.00 − 0.01 = 0.99.

Reliability = probability × probability

Considering a system with two components, the overall reliability equals the probability of success of one times the probability of success of the other. If the second component had a reliability of 0.8 per unit, and each component had only one unit, then the system reliability would be:

$$(0.9) \times (0.8) = 0.72.$$

A system with two units of component one and one unit of component two:

$$(0.99) \times (0.8) = 0.792.$$

And so the calculations could go with respect to reliability. The object, of course, is to maximize reliability subject to weight and cost restrictions.

Maximizing a complex probability function subject to restrictions can be handled by using the techniques of mathematical programing. It can be extended to systems with considerably higher number of components, possible numbers of units, and nonlinear restrictions in more than two dimensions. The major difficulty lies in the considerably large numbers involved quite frequently. Moreover, it isn't easy to define a system as a collection of functioning components. When such a point is reached, the design problem would seem almost to be licked.

The real opportunity for the extension of mathematical programing techniques lies in working with specific design problems in all fields of engineering to *identify* "components" or elements of the process. Characterization of restrictions also is needed. These aren't too obvious, but they should appear during the design process.

Your reaction, please?

Experiences in objective design may seem inconclusive to some, eye-opening to others, perfectly natural to still others. Mathematicians and mathematically oriented scientists tend to look upon such work as mildly naive and not yet possible; engineers are likely to feel a distinct danger to their status and activities as this form of "automation" moves in on them.

Thus the primary source of energy in motivating research necessary for complete realization of a theory of design must come from the managerial ranks where the economic facts of life are clear.

As progressively more complex hardware systems are conceived, implementation becomes progressively more lengthy. The "design phase" currently is dragged out to interminable lengths in many instances and is rather archaic when considered against the very results of that process. Managers of engineering activities and far-sighted philosophical engineers cannot help but feel an urgent need for a major breakthrough in design.

Two general courses of action are possible. One is to speed up standardization and information retrieval programs. Such a course requires only managerial vigor.

The other is the mathematical, statistical, and computer attempts to capture basic relationships of past experiences. This course is fundamental methodological research requiring more planning and longer range effort than may be palatable to many. It will be done, probably piecemeal, but it can be accelerated to the vast benefit of our national engineering effort with the active support of major research organizations.

Marketing a design system

It is not inconceivable that a particular company can gain considerable proprietary benefit from a "system" either in the marketing of it, or, more likely, in the 10-fold (or more) increase in company engineering effectiveness. A design system would reduce engineering costs and vastly increase engineering capacity to tackle new and more profitable projects.

There is no theory of design as yet —only some primitive notions and miscellaneous experiences that support the notions. A theory is on its way, however. Whatever form it takes, whether mathematical or heuristic, more attention must be paid *at the practicing level. (See Industrial Research, Vol. 1, No. 2, pp. 64-70.)* Only by feeding back specific design experiences and watching the process in action can progress be made. All have a very important part to play as we move toward a theory of design. ■

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Realistic Research Administration

THE PROBLEM:

How do you combine the unique situations and people of industrial research to build scientific knowledge, apply this knowledge to the betterment of man, and provide for profitable perpetuation of the corporation?

THE ANSWER:

By channeling all administrative matters toward increasing productivity of the research mind. This can be accomplished by increasing output during time spent on technical matters, decreasing interruptions and handicaps, and by directing efforts toward avenues offering the greatest promise and reward to the company and research worker.

THE AUTHOR:

Harold W. Rice, *director of research, Western research center, Robertshaw-Fulton Controls Co.*

IN THE STUDY of research administration, we read and listen to lectures for hours, become well acquainted with the subject academically, and discover that the process is basically a simple, logical sequence of events. We are confident that we completely understand the unique situations and people of research, until we try to apply our "complete" understanding. Then we are impressed once again with the limits of our knowledge.

As we attain this degree of discernment, we begin to adopt a professional approach — the approach suggested in this article — toward solving the specific problems of our work in the administrative areas of research objectives, budget, personnel, organization, project selection, scheduling, and facilities.

For our purposes, research is defined as a venture which, with as much logic and organization as possible, seeks to add to man's knowledge, and applies such knowledge to the betterment of man. At the same time, the objective of industrial research is self-perpetuation of the corporation. Research is oriented toward future profits.

The final results of research, however, are mere raw materials, of no value to a corporation unless implemented by further engineering, tooling, production facilities, and marketing activities. Thus, an important objective of research administrators should be to reduce research results to profitable production.

Nebulous dollars

When research budgeting is discussed, it usually is pointed out that the approvers of funds are accustomed to appropriating only for carefully described products and results, and therefore often have difficulty understanding that nebulous activity

As director of research at Robertshaw-Fulton's Western research center, Harold W. Rice has broad experience in technical management. Joining the company in 1935 as a draftsman, he progressed successively to engineer, head of laboratory, development engineer, project supervisor, and director. He is a registered professional engineer in California and holds 14 patents. Rice is a magna cum laude graduate of the University of Southern California and holds a BE degree in mechanical engineering.

In motion, direction

called industrial research.

However, this rationalization ignores the fact that for at least 300, possibly for 3,000 years, these same executives have been approving princely sums for advertising and sales. Generous amounts have been spent, not for tangible pieces of merchandise with well-defined characteristics, but for the results which an executive's vision told him could be achieved.

The executive did not see his vision alone. Advertising and sales managers were there to point out past successes and future benefits, in technicolor.

When the research director's budget is up for approval, he might do well to take a leaf from the same book. Certainly the results of research can be predicted in prospect and evaluated in retrospect at least as accurately as can the results of advertising and sales. The director can prepare the way by keeping management vividly aware of the status of research work. This should be conveyed to the executives graphically enough so that they visualize not only the present status, but future possibilities, and with as much optimism as justified.

How much to spend: maximum

The actual amount spent on research should be a midcourse among several quantities, each evaluated on a different basis. A firm can't spend so much that it has nothing left to invest in tooling and promotion, nor can it long spend so much that profits are wiped out.

XYZ Co., for example, actually was successful in developing a fuel cell for a specialized application. But to fit the detailed specifications of the application, almost $3-million was required for the design of an engineering prototype and production equipment. Because the budget was expended in the research, no funds were available for tooling, and the project was scrapped.

A point often neglected is that a research budget should be just a little less than the willingness of the company to exploit results of its research. A company that spends money on research without having set aside venture capital for exploitation of research results is buying a useless commodity.

A classic example of the need for having reserve funds available for exploiting a new development is the case of the powdered coffee manufacturer who couldn't understand why sales were slow (see *Industrial Research*, Vol. 1, No. 1, p. 82). Fortunately for the company, and for the fate of instant coffee, the manufacturer had the foresight and funds to turn to a psychologist for assistance.

Results of the psychologist's study revealed that women resisted instant coffee because it represented a lazy woman and one who would not plan her purchases well. The manufacturer immediately changed his advertising message—and the image of the consumer—to show good planning and thrifty buying. The result: instant coffee is here to stay, and the manufacturer is realizing a profit from his research.

Of course there is an optimum rate of expenditure for maximum efficiency. Forcing too much money into a research project tends to produce duplication of efforts, repetition of steps, and an impetuosity which discourages creative thought.

How much to spend: minimum

The minimum to be invested should be the amount required to keep a company progressing at a reasonable rate, to keep it ahead of its competition, and to provide insurance on the capital investment.

If the company has a large investment in single-purpose equipment to produce a highly specialized product, it must spend a considerable amount on research to make the market for that product more stable, and to find alternate uses for its equipment.

Let's assume that the same XYZ Co. described above had been able to invest the millions of dollars required to carry development of its fuel cell through to production. Because of the specialized application of the new development, XYZ would have been faced with the problem of creating and stabilizing a market, and possibly, finding additional uses for its equipment in order to protect its investment.

If a company has growth plans, research efforts should be large enough to support that growth.

The research expenditure preferably should be generous enough to allow the research group to carry on a diversified program.

Above all, to produce the greatest effect, spending must be maintained at a consistent rate. It costs money to build up research intensity—and it costs money to decrease it.

Down the elevator shaft

While proper budgeting is vital to the efficiency of a research organization, the core of the department is its personnel. Selection of research personnel is like the proverbial first step down the elevator shaft—a difficult step, but after it is successfully taken, the rest is easy.

The ideal research scientist is an unusual person. His efforts are difficult to evaluate, and his motivation is his own drive.

All good research personnel are not highly creative, nor should they

s more important than speed . . . in motivating the research mind, an even more important function of the administrator is to interpret and break down overall objectives of the research udget into attainable goals tailored to the group and the individual.

be. An organization must have a proper balance between creative people who provide the raw material ideas, and the relatively less creative who carry through these ideas to a final laboratory product. Nevertheless, it is the output of the creators in an organization which largely determines effectiveness of the group.

The creator is neither average nor difficult to understand. He usually has a high level of intelligence, particularly in numerical reasoning, logic, spatial visualization, and mechanical comprehension. He probably has a strong mental (as opposed to emotional) discipline. He is more interested in things than people, and he has a greater understanding of and patience with the inanimate than with the animate. He often is dissatisfied with the people and objects around him. He wants to change and improve objects, but seldom people.

The creator tends to be an individualist and a non-conformist, but he may like group work. He loves to learn. He enjoys research because of a strong desire, if not dedication, to improve, create, and construct.

The creator takes great pride in his accomplishments. He expects others to recognize and appreciate the value of his work, and is disappointed if they do not. He may enjoy arguing for hours about the accuracy or technical excellence of his work, but he will feel that the need for the work should be apparent.

He particularly wants freedom of choice. He frequently can see possibilities in venturing up new avenues. Flexible as a wet noodle, he can be led or drawn in a general direction, but never pushed.

Motivating creators

Too many research administrators focus attention on increasing the productivity of people with sub-normal output. There is a much greener field to develop—increasing the output and effectiveness of those fewer creators whose productivity already is greatest.

A given amount of attention focused on a productive person will bring a greater percentage increase in output than the same attention and help spread among poorly productive people.

One effective method of motivating the creative research scientist is to subsidize memberships in professional societies and industrial associations. (It's good advertising for the company, too!)

Another is to give the research man an opportunity to talk about his work with other technical men in his company, for such discussion helps him evaluate his progress.

In considering progress, remember that on long, difficult projects, progress may be so slow that the researcher doesn't notice it. The administrator then should point out this progress to give him the encouragement that comes with progress.

The research worker is unusually curious, and should be supplied with more than the usual amount of information about company activities. He can be influenced greatly by his impression of the company's attitude toward him and toward research in general.

Money and the man

Salary is another individual factor in the motivation of employes. But the things that money will buy, rather than the money itself, are of interest to the typical research worker. He usually recognizes money as a useful tool—even a necessary one—but he seldom seeks it for its own sake. Usually, he forgets about money, devotes himself to his work, and relaxes at other times.

It would seem, then, that the best salary policy for research organizations is one that pays an adequate salary, but which does not focus needless attention on the subject.

Industrial Research will be monthly beginning with the next issue—a special edition devoted entirely to Energy Conversion.

Fringe benefits are becoming more important parts of the salary structure for the researcher. The inclusion of insurance and pension benefits allow him to thrust aside financial problems and devote his attention to his first love—research.

The age of creativity

In discussions of the influence of age on motivation, it has been argued by some that creativity declines noticeably in the research scientist after age 30, while others insist that creativity depends upon an attitude having nothing to do with age.

Creativity should continue and, in fact, improve with age. Benjamin Franklin, for example, was 46 years old when he invented the lightning rod. At 54, he developed the bifocal lens. Thomas A. Edison invented the phonograph at 30 and built the first workable motion picture projector at 46. Also at the age of 46, Samuel F. B. Morse invented the telegraph.

Possibly younger people seem more creative because of the help being given them by older members of an organization. There also is some possibility that a trend toward shifting people from research into production and administration tends to eliminate older employes from the creative group.

Yes, it is important to motivate the researcher—but as in all motion, *direction* is more important than speed. An even more important function of the administrator is to interpret and break down overall objectives of the research budget into attainable objectives. These should be objectives, tailored to the groups and individuals, that can be seen and sought by them, but which now are just beyond reach. Without these visible objectives, the researcher may work aimlessly.

Finding the right question

The research group should direct as much effort toward project selection as it expends in carrying out a project. A crucial part of a research job is uncovering, as well as answering, questions. The number of right answers increases with the number of right questions.

Although project ideas should be thought out carefully before research is started, laboratories can carry preliminary screening too far. They can wait so long to find the foolproof project that they never get around to doing the research.

Project selection can be likened to the problem of what to do with a pile of oysters. A project leader might assume it would be worthwhile to open his oysters only if he could find enough pearls among them. Then he's plagued with the problem of selecting only those oysters from which he has the best chance of getting pearls. Neither the pearl business nor the research business could survive with this attitude.

Why not open all the oysters and at least use the shells for buttons?

If the laboratory procedes with the buttons, keeping a sharp eye out for pearls, it usually finds so many pearls that it never gets around to the buttons. The pearls are breakthroughs in existing projects, or new exciting ideas suggested by existing work.

A very important step toward finding the right questions is effectively keeping in touch with the outside world—and particularly with the needs of customers, the accomplishments of competitors, and the activities of other parts of the company. The research program should have stability—but not inertia. It should adapt itself (alertly, not turbu-

lently) to changing conditions within its company, its customers, and its competitors. The research administrator *must* take an active part in this communication, and foster it diligently.

One effective method of project initiation starts with the writing of an abstract outlining project objectives, background information, possible advantages, and time estimates. Available approaches and chances of success sometimes are described.

These project abstracts are reviewed by informal groups in which the interests and backgrounds represented are pertinent to each proposed project. Finally, the abstract is examined by the research administrators. (For a large project, the report also is reviewed by company executives.) If preliminary approval is obtained, the project is begun. Evaluation is repeated often during the progress of the project. An important phase of the project itself is the initiation of any market research necessary for proper evaluation.

The project is assigned to the person who originated the idea. If this is not practical, it is assigned to someone who indicates a strong interest in it and whose training is adequate for the job.

The project leader is encouraged to take his time in planning and laying foundations for the research. Once his course of action has been determined, however, he is expected to act rapidly—using telegrams, long distance calls, and personal visits whenever expedient. He is expected to make as many decisions as he can on the basis of his familiarity with the project.

The administrator should keep in touch with the project to inject a fresh idea or approach if the project seems to be lagging.

Relative priorities of projects are reviewed informally from time to time. Each scientist usually is assigned several projects, with one more urgent than the others. In this way he can make most efficient use of his time.

Scheduling research

Scheduling is always a ripe subject for argument in research administration. Some insist that research cannot be scheduled, while others feel it must be scheduled to get results. Actually, scheduling can be an effective *aid* to a project, but it should not be so rigid as to run the work.

Scheduling allows planning of such service functions as obtaining special material, building prototypes, and using special test equipment. It also helps communicate the urgency of the work.

A potential danger in scheduling, however, grows out of the fact that research progress, like any other learning process, is roughly "S" shaped. In the initial stages, progress is rather slow. When enough information is at hand to spark ideas, progress accelerates until most of the ideas have been implemented. Then progress tapers off until a new cycle begins.

If a rigid schedule is followed, a

IDEAS AND APPLICATIONS #1

THE PROBLEM: *Air traffic congestion and jet noise in big cities.*

THE SOLUTION: *A unique method of constructing artificial islands for jetports.*

Artificial islands can be built relatively economically in water with a depth of 50 feet or less, according to Alexander Riff, contract engineer at Raymond International Inc., 140 Cedar St., New York 6. Such islands could extend premium real estate of big-city downtown areas located near water to relieve air traffic congestion.

In one plan, five 200- to 400-ft. breakwaters would form a pentagon to be filled with sand to provide a support for runways. Each breakwater would have an equilateral triangular cross-section as high as the depth of the water in which the island is built. The triangular shape not only is structurally sound and easy to build, but can be sunk with greater control than other shapes.

After the breakwaters are connected, sand would be filled by normal dredging methods displacing the water. If such an island were built fairly close to shore — say a mile — an added advantage is that fill sand could be taken from near the shore. In this way, a channel could be deepened or a small harbor constructed at the same time.

The island would be connected to the mainland by conventional causeways.

Riff told an Industrial Research editor that the plan already has been submitted to the New York port authority. Other areas of possible application are in San Francisco Bay, in Lake Michigan off Chicago, or by any municipality adjacent to water. In Tokyo, where real estate prices are higher than anywhere else in the world, the plan could be utilized to provide land for large buildings. ■

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project easily could be considered completed when it is merely entering the period of most rapid progress. Such an artificial deadline could chop off the most fruitful phase of a project. The schedules also should be easily changed to shift priorities in response to changing conditions.

An optimum speed exists for any project. If a project is rushed, the results may suffer because there has not been enough time for ideas to percolate. On the other hand, there is real danger in allowing a project to drift along. Informal, periodic reports during the progress of the project help to eliminate these pitfalls. Such reports, of course, should be kept to a minimum.

When to stop

The first step in completion of a project is simply the recognition that it is completed. A particularly successful project should be studied carefully to avoid the inclination to continue out of sheer enjoyment of its success!

There is a strong tendency to continue a project despite indications that the project is unwise, because of the money already put into it. One of the purposes of repeated evaluation of projects is to point out those projects which have reached the point of completion, successfully or unsuccessfully.

Determining how far the research organization should carry a successful project is a recurring problem. At times, management prefers that the research organization conduct pilot runs and life tests before the product is put into production. In other cases, an engineering group may carry out the development and pilot production design work. The choice depends upon the novelty of the product, and upon the relative work loads in research and engineering.

Transfer of responsibility from the research organization to the product-engineering group is a crucial point in the life of a project. Every effort should be made to ensure that the product-engineering group is receptive to the new idea, and that it properly utilizes the idea. Some of the most effective results of research are deceptively simple, and their advantages may be overlooked and even changed by production engineering unless explained clearly.

Organization to serve the organized

Most research personnel are not organization-prone; they dislike red tape. A detailed organization with rigid outlines, from general to private, not only is unnecessary, it easily could be a handicap. Changes in organization should be made when required, but as smoothly as possible. Violent organizational changes can be a very disconcerting interruption to research work.

In our firm (Robertshaw-Fulton Controls Co.) a relatively new type of organization which has produced good results is being used at one of the centers. The center is headed by a general manager responsible for expenditures and results.

IDEAS AND APPLICATIONS #2

THE PROBLEM: *Cement failure in applications where continuous temperatures above 4000 F must be withstood along with repeated, severe thermal shock.*

THE SOLUTION: *Development of an adhesive having an extremely low coefficient of expansion and high bonding characteristics to ceramics, refractories, quartz, and metals.*

A maximum service temperature of 5300 F is possible with Astroceram adhesives developed by American Thermocatalytic Corp., 200 E. Second St., Mineola, L.I., N.Y. Recent tests also confirm excellent resistance to radiation in nuclear reactor work, according to Kurt W. Cornely, chief chemist.

These high-temperature cements can be used in casting of welding and brazing fixtures, and in crucibles. Glass, quartz, zirconia, alumina, refractories, ceramics, and metals have been bonded with Astroceram. The cement also has use as a dielectric for capacitors, potting of electronic components, sealing feed-through insulators, and as a mortar for firebrick in high-temperature furnaces. Firebrick can be upgraded by a surface coating of the cement to withstand extremely high temperatures.

Astroceram can be used in place of ceramic and metal sheaths to encapsulate thermocouples for improved heat transfer and chemical and thermal resistance. The cement currently is under study in the atomic energy field, and to determine its adaptability for the manufacture of missile nose cones.

Astroceram does not react in contact with metals or ceramics because it forms "saturated" compounds. The coefficient of thermal expansion is 5×10^{-9} inch per degree F. Thermal neutron cross-section ranges from 20 to 30 Barnes, and thermal conductivity is in the order of 23.2 Btu/hr. ■

He is assisted by a small group of office personnel and by the director of research, who is responsible for technical direction of the programs. A number of project-oriented groups, each covering an area of work and each headed by a group leader, report to the director of research.

This method of organization frees the research director for research direction, a common-sense but rare approach to technical administration.

The geographic separation of research from production also is an important aspect of an efficient setup. Pressures applied by manufacturing, cost accounting, and sales organizations can seriously hamper long-range planning. It's too easy to borrow the services of competent research people for "red-hot" projects that always crop up.

Some criticism can be expected when the research activity not only is separated from the production plant, but also split into two centers as it is in our company. However, communication between the research centers and between them and the manufacturing divisions prevent any sizable duplication of effort.

Actually, a spirit of cooperative competition between two centers is healthy. Each keeps the other informed of progress and of outside contacts in interest. Each tries to outdo the other in ideas, and each may contribute different approaches to the same problem.

Realistic accomplishments

Accomplishments of the research laboratory are neither accomplishments of research administrators nor of machines, but of the minds of research personnel in the laboratory. Recognizing this basic fact, the realistic research director will channel all administrative matters toward increasing productivity of these research minds.

How can this be accomplished? By increasing output during the time researchers spend on technical matters; decreasing interruptions, diversions, and handicaps which detract from time spent on technical matters; and particularly by directing researchers efforts toward avenues offering greatest promise.

Nor should the research administrator forget that research does not stand alone on a high hill. If he wants cooperation of others in his company and industry, he must be the first to acknowledge that his department is not above and apart from the rest of the world.

The realistic approach to research administration is, in essence, the common-sense approach. ■

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(1) *Chemical Processing, Dec., 1960, p. 29.*
(2) *Chemical Engineering, Dec. 26, 1960, p. 88.*
(3) *Address by E. V. Murphree before American Chemical Society.*
(4) *Fishing for Facts: Firms Add Specialists to Handle Rising Tide of Scientific Papers, Vol. XLI, No. 47.*

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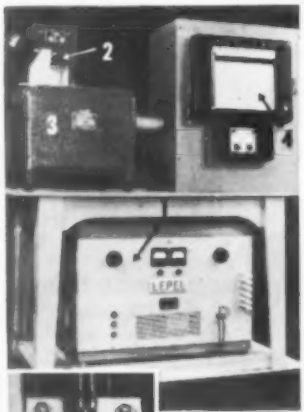

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Sen. Hubert H. Humphrey (D., Minn.) chairman, Senate government operations subcommittee, science study:

"The federal government's 'Model T' methods of managing scientific information contribute to unknowing duplication and tragic and intolerable waste of men, money, and material. There is no indexed inter-agency inventory of an estimated 160,000 projects, involved in $8.1-billion of current federally financed research and development projects.

"Sufficient attention has not yet been given to the problem of salvaging results from the vast investment in contracts and subcontracts which are canceled prior to producing finished hardware. More than $2-billion such contracts and subcontracts were canceled in the last three fiscal years.

"A great many research projects are never reported in talks to professional societies or written in technical journals. This may be because experiments fail. Yet, it is essential that science learn about tests which had negative results, so that, in part, scientists will not go on endlessly repeating futile experiments."

Richard S. Morse, assistant secretary of the Army, before Institute of Aerospace Sciences, Washington:

"The fact that a man is a scientist or engineer by training or reputation does not necessarily mean that he also is competent to manage and divert programs. This country as never before needs technical management talent—talent that also is willing and eager to work in cooperation with out military people. Technology can lead us to disaster or to a more advanced civilization depending upon the results of the military's efforts."

Morse, before The American Institute of Chemists, Washington:

"If the research and development programs in communications satellites being done by the government were combined with an equal effort from industry, we would develop a system that permits person-to-person dialing throughout the world and world-wide TV facsimile programs. This is just one of many government research projects which have great commercial potential and must evolve rapidly if we are to demonstrate the effectiveness of free-enterprise to the world."

Henry Ford II, board chairman, Ford Motor Co., at Southern Research Institute, Birmingham, Ala.:

"There is only one workable way for us to meet the challenge of friendly competition. That is to be more competitive. We must trade more, not less; exchange more, not less, of goods, capital, and technology.

"If we want to participate in Europe's rich automotive market, we must do so largely from the inside—through investment.

"If we want to share in those markets, rich and vast as they someday surely will be, if we want to have some influence on how they grow and where they are headed, we are going to have to do so mainly from the inside."

Dr. Jonathan Karas, president, Jonathan Karas & Assoc., after manned Soviet space flight:

"Since 1957 radio and television stations have been informing the public about lack of a definitive educational plan, lack of American understanding, and other changes which must be made. Yet these same stations have made no moves to obtain scientific counsel in preparing to report scientific news to the public.

"They should learn a lesson from progressive newspapers and magazines that recognize the value of science writers and editors to cover and report scientific news.

"I sincerely hope that when someone lands on the moon, reporters will refrain from asking scientists whether this is significant."

Van M. Evans, executive vice-president, Deutsch & Shea Inc., in an open letter to engineering societies:

"The time has come to call a halt to all convention recruiting. Such a step would be welcomed by many corporations that participate in convention recruiting campaigns only because they feel they must be represented at these gatherings or lose out in the competition for technical manpower. Such defensive recruiting would not be necessary if no recruiting at all were carried on during conventions.

"In the interests of removing from these meetings the 'market place' stigma they have acquired, I suggest:

- That the major societies reach an agreement to ban all interviewing, hospitality suites, and advertising for the

purpose of promoting recruiting interviews during meetings and conventions of the societies.

■ That the societies jointly request all companies employing engineers and scientists to desist from such recruiting efforts, including the use of outside groups or individuals acting as agents for the company, during the days of meetings and conventions.

■ That the societies urge their members to cooperate fully in this action as a means of freeing professional meetings from the distractions and encumbrances of recruiting efforts."

T. G. LeClair, manager, nuclear power applications, General Dynamics Corp., before the American Power Conference

"The downward trend in the cost of nuclear power is so pronounced that the development and construction of plants should be pushed to achieve our goal of competitive power. We have come far enough along the road to have confidence that the atom will be an important addition to our sources of energy for the future.

Burton Browne, president, Burton Browne Advertising, before electronic sales managers, New York:

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Dr. Albert C. Hall, engineering vice-president, The Martin Co., before financial analysts, Richmond, Va.:

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"Preoccupation with missile propellants does not particularly serve the public interest, because the overriding criterion of rocket capability is not what makes it go, but why and where we want to go. In short, we ought to be asking questions about missions, not detailed means; about purposes, not specific propellants.

"Today we are using liquid and solid fuel rockets; tomorrow, they will be supplemented and in many respects supplanted by nuclear rockets."

Dr. Harlow Shapley, former Harvard Observatory director, at newspaper editors convention, New York:

"Galaxies, bugs, bees, apes, and editors—all have evolved from hydrogen."

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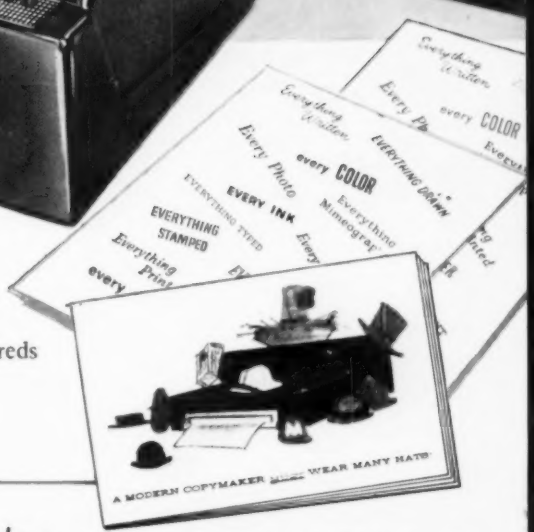

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